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JICM 1.0 Summary

Bruce W. Bennett, Arthur M. Bullock,
Daniel B. Fox, Carl M. Jones, John Schrader,
Robert Weissler, Barry A. Wilson

National Defense Research Institute

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Director, Net Assessment, Office of the Secretary of Defense

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Preface

This report documents the Joint Integrated Contingency Model (JICM) version 1.0. JICM, which is based on both new research on the future of warfare and new procedures for modeling, is designed for post–Cold War analysis. It is an outgrowth of the RAND Strategy Assessment System (RSAS), developed originally a decade ago. JICM development was sponsored by the Director of Net Assessment in the Office of the Secretary of Defense (OSD/NA) and was performed within the International Security and Defense Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies.

The purpose of this document is threefold. First, the report summarizes the development status of JICM 1.0, released in December 1993, describing each JICM component that has changed and how it has been changed since the completion of RSAS 4.6 in FY91.[1] In particular, it provides the initial documentation of the Integrated Theater Model (ITM), developed to enhance and simplify theater analysis. Second, it provides basic user instructions for many parts of the JICM, as a starting point for users to work with JICM 1.0. Third, it provides some information on known limitations and important directions for future JICM development to assist in the planning of JICM efforts. In addition, a wide range of JICM documentation has been written and is in the process of being written, as described in Appendix A.

This document is intended for JICM users and prospective users. Secondarily, it is for all analysts interested in major regional contingencies.

Comments and inquiries are welcome and should be addressed to the principal author or to Charles Kelley, Director of the International Security and Defense Policy Center.

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[1]Bruce W. Bennett et al., *RSAS 4.6 Summary*, RAND, N-3534-NA, 1992.

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Summary

The Joint Integrated Contingency Model (JICM) is a global war gaming and analysis system that focuses on conflict from major regional contingencies through strategic warfare. JICM is an outgrowth of the former RAND Strategy Assessment System (RSAS), engineered explicitly to address post–Cold War conflict issues.

JICM has been developed to support balance assessment, contingency analysis, and military training. It is a global system because it includes, as part of its release, order of battle data for most major countries worldwide, relieving JICM users of the burden of having to develop such information. (It contains current and projected force data for many countries.) It also includes four baseline cases, covering conflicts in Poland, Turkey, the Persian Gulf, and Korea.[1] These cases have been developed to support the Global Series of war games sponsored by the U.S. Naval War College and other JICM applications.[2] Thus, the JICM comes as a ready-to-use package, although users will also find it easy to develop new theaters for analysis in the JICM.[3]

JICM 1.0 includes development through FY93. Once complete, it will be transferred to selected Department of Defense agencies for use in analysis, gaming, and training.

The JICM has evolved significantly since the release of RSAS 4.6 in late 1991. The major task in this period has been the development of the new Integrated Theater Model (ITM) for the JICM, which combines the two former RSAS theater models (CAMPAIGN-MT and CAMPAIGN-ALT) to make theater analysis easier, and provides numerous substantive enhancements to the procedures used in theater analysis, based on our research into the future of warfare and our experience in model use and gaming. Principal enhancements included in ITM are

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[1]Variants of these baseline cases have been documented in RAND Notes done on the Global war games, as described in Appendix A.

[2]Many theater models require new users to develop their own baseline scenarios, and others include only historical cases (e.g., conflict on the inter-German border) that are of little relevance today. A major component of the RSAS and now JICM effort has been to continue to provide a complete package from which new users can begin training and incrementally change to their required application, rather than having to do months of data base preparation before ever using the model.

[3]See, for example, how an India-versus-Pakistan contingency was added in Dave Lee and Dan Fox, "A Test Case for Making the RSAS Easier to Use," *Military Science & Modeling*, August 1993.

- Development of an integrated land geography and networks. Places are now defined and are connected with links that form the basis for administrative and combat movements. Locations are now defined in terms of places rather than by region, as was done in the RSAS (see Section 3 for details).
- Provision for full operational maneuver across the land network. Both CAMPAIGN-MT and CAMPAIGN-ALT were limited to combat movements along a "piston"; ITM allows movement in any direction along any part of the network, and defines combat interactions whenever opposing forces come into contact in any configuration (frontal contact, flank contacts, rear contacts, and internal—security—contacts). JICM commands (often reflecting real-world corps) are the key entities to maneuver over the network, although individual forces outside the purview of their command can also be involved in contacts.
- Enhancement of battle definitions, which include factors such as the various components of the Situational Force Scoring (SFS) methodology (posture, terrain, force shortages, and casualty distribution), separate adjudication of artillery fires in a weapon-on-weapon framework, artillery fire suppression, and the effects of various other fires (air, attack helicopters, and long-range artillery such as the Army Tactical Missile System [ATACMS]). Battles are constrained by the logistics tail of the attacker and the efforts of both attacker and defender to move massed forces along limited lines of communication. Battles may conclude in a failed assault, a breakthrough, or a defender's withdrawal; battles are not assumed to be continuous (in contrast to some theater models that assume continuous assaults of weeks' duration).
- Reorganization of air tasking in a theater to follow the basic pattern of an air tasking order (ATO). The ATO is derived from guidance on use of multirole aircraft, division of air-to-air sorties and air-to-ground sorties into mission areas, packaging[4] of aircraft to perform specific missions, timing of sorties in each mission category, and allocation of mission sorties to specific targets. The development of the ATO is done in C-ABEL code, enabling users to make changes in procedures, if desired. The product of the ITM ATO planning process is a list of aircraft packages (and the aircraft within each package) designating the activity and timing of the package, as illustrated in Figure S.1. To better parallel the real-world ATO, cruise missiles (e.g.,

[4]*Packaging* is the combining of aircraft assigned differing missions into a single flight or group to achieve the synergies of the separate missions.

7USAF ATOs for Period 2:

ID	Squadron	Aircraft	Mission	#	Target
3	8-TFW/1-TFS	A-16	BAI	4	KS_CC>>4-Corps/1-ID
	8-TFW/2-TFS	F-16C	Escort	1	
	8-TFW/1-TFS	A-16	SEAD	1	
4	8-TFW/1-TFS	A-16	BAI	4	KS_5C>>5-Corps/1-MXD
	8-TFW/2-TFS	F-16C	Escort	1	
	8-TFW/1-TFS	A-16	SEAD	1	
21	8-TFW/1-TFS	A-16	OCA	4	Pukchang Air Base
	8-TFW/2-TFS	F-16C	Escort	2	
	8-TFW/1-TFS	A-16	SEAD	1	
33	8-TFW/11-TFS	F-16C	AI	2	12-Corps/1-MXB
	8-TFW/12-TFS	F-16C	Escort	1	
	.....				

Figure S.1—Sample Packages from the ITM ATO

theater land-attack missiles [TLAMs]) and other systems can be included in the ATO. See Section 5 for details.

- Execution of the ATO by package, and adjudication of air combat results to recognize the contributions of each component of the package, including suppression of enemy air defense (SEAD) aircraft, escorts, and mission aircraft.
- Development of an amphibious operations model integrated with ITM. It includes adding amphibious lift to the JICM ship data base, using this lift to move selected amphibious (Marine) units, designating beach areas for assaults, providing logic associated with amphibious assaults, and making a transition from the amphibious assault to the ITM combat network. See Section 6 for details.
- Development of a new map graphics package called JICM Map. JICM Map is closely tied to ITM, allowing the user to observe combat interactions on a map, as shown for the central part of Korea around the Chorwon Valley in Figure S.2; the user may touch map symbols to obtain greater detail on the conflict situations, an example of which is shown in Figure S.3.[5] All graphics inputs come directly from CAMPAIGN (rather than from separate, static

[5]JICM Map is documented in Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, RAND, MR-122-NA, 1993; an updated version of this report exists as an unpublished RAND draft.

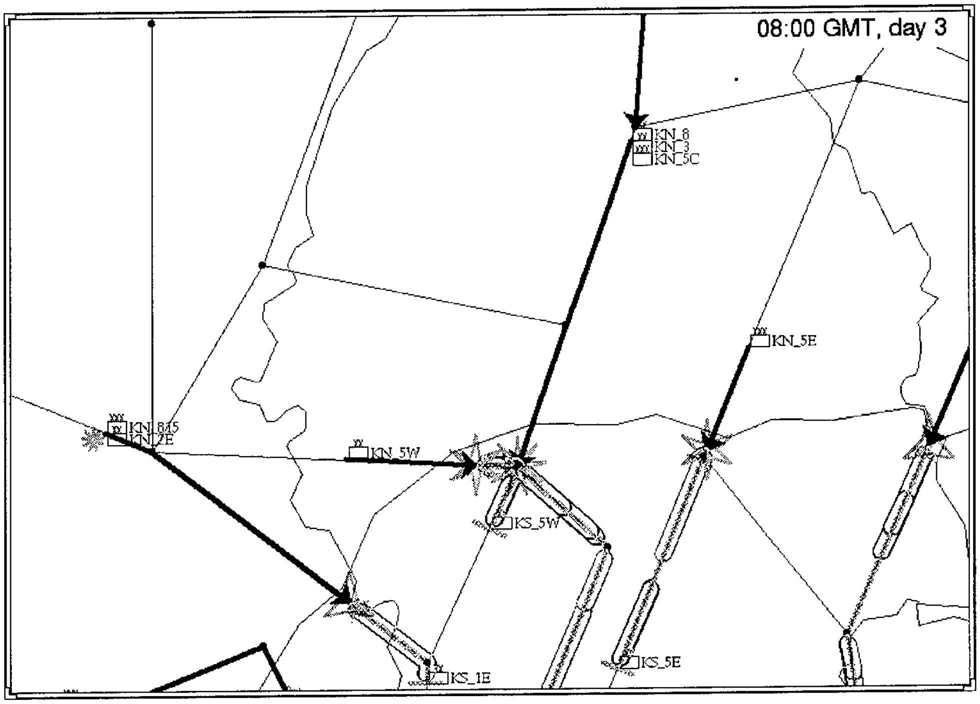
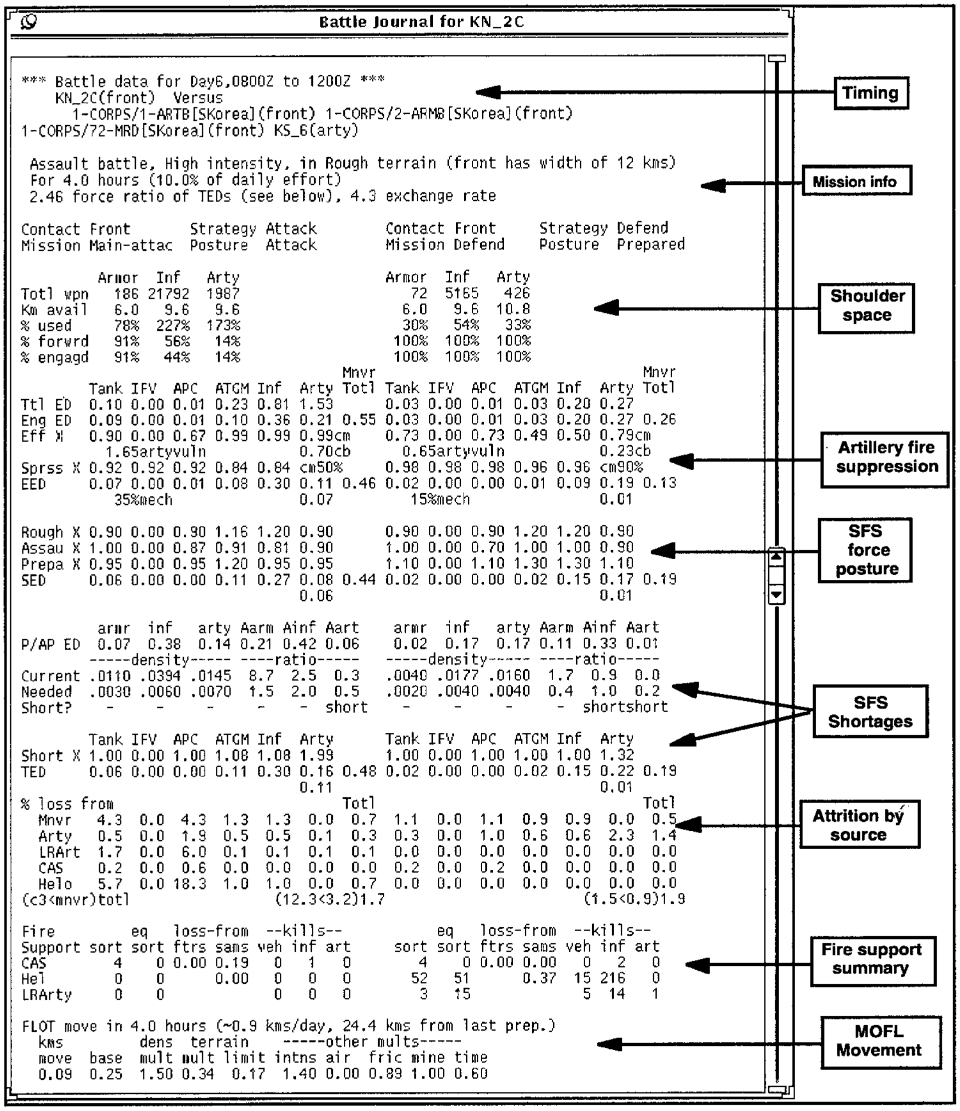


Figure S.2—State of the Central Korean Battlefield, with Multiple Battles

files, as was done in the RSAS) and, thus, reflect the true current state of the simulation; the new Sun ToolTalk utility is used as the basic communications interface by JICM Map.

- Enhancement of the English-readable language RAND-ABEL®[6] to allow for a full range of data structures and other variable formats. In turn, the enhancement facilitated the development of C-ABEL, a version of RAND-ABEL that is thoroughly integrated with the C language programs of CAMPAIGN, without connection to the World Situation Data Set that supports the RAND-ABEL portion of JICM (WSDS-A) or other parts of the traditional RAND-ABEL environment (including the Interpreter). ITM was developed using the general philosophy that substantive parts of ITM should be coded in C-ABEL to make them more transparent and easier to change, whereas bookkeeping and other difficult aspects of ITM should be done in C to make them more efficient and hide them from the analyst, discouraging attempts to change code that might lead to unexpected errors and other problems. The user may also define control plan logic and incorporate it into C-ABEL.

[6]RAND-ABEL is a registered trademark of RAND.



```
Battle Journal for KN_2C

*** Battle data for Day6,0800Z to 1200Z ***
    KN_2C(front)  Versus
      1-CORPS/1-ARTB[SKorea](front) 1-CORPS/2-ARMB[SKorea](front)
1-CORPS/72-MRD[SKorea](front) KS_6(arty)

 Assault battle, High intensity, in Rough terrain (front has width of 12 kms)
 For 4.0 hours (10.0% of daily effort)
 2.46 force ratio of TEDs (see below), 4.3 exchange rate

Contact Front       Strategy Attack        Contact Front      Strategy Defend
Mission Main-attac  Posture  Attack        Mission Defend     Posture  Prepared

         Armor  Inf   Arty                 Armor  Inf   Arty
Totl wpn   186 21792  1987                    72  5165   426
Km avail   6.0   9.6   9.6                   6.0   9.6  10.8
% used     78%  227%  173%                   30%   54%   33%
% forwrd   91%   56%   14%                  100%  100%  100%
% engagd   91%   44%   14%                  100%  100%  100%
                                     Mnvr                                 Mnvr
        Tank IFV  APC  ATGM Inf  Arty Totl Tank IFV  APC  ATGM Inf  Arty Totl
Ttl ED  0.10 0.00 0.01 0.23 0.81 1.53      0.03 0.00 0.01 0.03 0.20 0.27
Eng ED  0.09 0.00 0.01 0.10 0.36 0.21 0.55 0.03 0.00 0.01 0.03 0.20 0.27 0.26
Eff %   0.90 0.00 0.67 0.99 0.99 0.99cm    0.73 0.00 0.73 0.49 0.50 0.79cm
          1.65artyvuln           0.70cb      0.65artyvuln           0.23cb
Sprss X 0.92 0.92 0.92 0.84 0.84 cm50%     0.98 0.98 0.98 0.96 0.96 cm90%
EED     0.07 0.00 0.01 0.08 0.30 0.11 0.46 0.02 0.00 0.00 0.01 0.09 0.19 0.13
           35%mech               0.07         15%mech               0.01

Rough X 0.90 0.00 0.90 1.16 1.20 0.90      0.90 0.00 0.90 1.20 1.20 0.90
Assau X 1.00 0.00 0.87 0.91 0.81 0.90      1.00 0.00 0.70 1.00 1.00 0.90
Prepa X 0.95 0.00 0.95 1.20 0.95 0.95      1.10 0.00 1.10 1.30 1.30 1.10
SED     0.06 0.00 0.00 0.11 0.27 0.08 0.44 0.02 0.00 0.00 0.02 0.15 0.17 0.19
                                 0.06                               0.01

         armr  inf   arty Aarm Ainf Aart    armr  inf   arty Aarm Ainf Aart
P/AP ED  0.07  0.38  0.14 0.21 0.42 0.06    0.02  0.17  0.17 0.11 0.33 0.01
        -----density----- ----ratio-----   -----density----- ----ratio-----
Current .0110 .0394 .0145  8.7  2.5  0.3   .0040 .0177 .0160  1.7  0.9  0.0
Needed  .0030 .0060 .0070  1.5  2.0  0.5   .0020 .0040 .0040  0.4  1.0  0.2
Short?    -     -     -     -    -  short    -     -     -     -  shortshort

        Tank IFV  APC  ATGM Inf  Arty      Tank IFV  APC  ATGM Inf  Arty
Short X 1.00 0.00 1.00 1.08 1.08 1.99      1.00 0.00 1.00 1.00 1.00 1.32
TED     0.06 0.00 0.00 0.11 0.30 0.16 0.48 0.02 0.00 0.00 0.02 0.15 0.22 0.19
                                 0.11                               0.01
% loss from                           Totl                                Totl
  Mnvr    4.3  0.0  4.3  1.3  1.3  0.0  0.7  1.1  0.0  1.1  0.9  0.9  0.0  0.5
  Arty    0.5  0.0  1.9  0.5  0.5  0.1  0.3  0.3  0.0  1.0  0.6  0.6  2.3  1.4
  LRArt   1.7  0.0  6.0  0.1  0.1  0.1  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  CAS     0.2  0.0  0.6  0.0  0.0  0.0  0.0  0.2  0.0  0.2  0.0  0.0  0.0  0.0
  Helo    5.7  0.0 18.3  1.0  1.0  0.0  0.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0
(c3<mnvr)totl                 (12.3<3.2)1.7                         (1.5<0.9)1.9

Fire          eq   loss-from  --kills--            eq   loss-from  --kills--
Support sort sort ftrs sams veh inf art       sort sort ftrs sams veh inf art
CAS        4    0 0.00 0.19   0   1   0          4    0 0.00 0.00   0   2   0
Hel        0    0      0.00   0   0   0         52   51      0.37  15 216   0
LRArty     0    0             0   0   0          3   15             5  14   1

FLOT move in 4.0 hours (~0.9 kms/day, 24.4 kms from last prep.)
  kms          dens  terrain    -----other mults-----
  move  base   mult mult limit intns air  fric mine time
  0.09  0.25   1.50 0.34  0.17  1.40 0.00 0.89 1.00 0.60
```


Figure S.3—The Battle Display for the Chorwon Valley

Dozens of other changes have also been accomplished, as detailed in Section 1 and throughout the text.

The JICM differs from many other military simulation models in that (1) it provides a global framework, considering conventional through nuclear conflict; (2) it includes numerous decision models and related software to assist in compiling and testing military operations and strategies; and (3) it is built around a philosophy of sensitivity testing, consistent with the uncertainties associated with major wars and national and military decisionmaking. Each of these factors significantly affects how the JICM can and should be used. Appendix C describes our expectations about JICM usage.

The JICM differs from most other military simulations in that it includes an ability to define military campaign concepts in the Command and Government Agents. These campaign concepts can be developed into Analytic War Plans (AWPs), which differ from traditional war plans in several ways:

- Although they include preparation for war, they focus on war execution, because AWPs are intended to reflect the decisions a military leader could make as combat conditions evolve (traditional war plans usually provide at most an outline for the actual campaign, leaving the details to the commander for his real-time decisions in the war).
- AWPs recognize that warfare is seldom executed from a linear plan, but rather evolves along a series of branches and other choices that reflect the uncertainty in warfare. As a result, AWPs include alternative courses of action and the conditions that lead to the choice of each.
- AWPs are developed not so much on the basis of military expertise as on the basis of a large number of analyses of conflict in a given area; AWPs allow the user or analyst to gradually evolve plans that respond to anticipated contingencies in a robust and consistent manner.

These campaign concepts are written in RAND-ABEL so that military planners can review the plans as developed and recommend additions and changes to them (that is, they can work directly from the source code and not have to work from a secondary description of that code).

In RSAS 4.6, the structure of the AWPs was changed from a bipolar organization to a multipolar organization, reflecting the changes in the world in the last several years. In this new structure, some 100 governments are represented by the Government Agent, which makes decisions about the preparation of national forces for war and the commitment of those forces to military commands. The Government Agent also includes plans for the use of strategic weapons on a national basis, such as the nuclear weapons of the United States or France. Otherwise, campaign plans are included in the Command Agent, which reflects military commands in command hierarchies and allows for multinational commands. Campaign plans can be flexibly organized in the Command Agent. They can also be developed in control plan format (which the JICM interprets at any phase during a game run) and structured to parallel Command Agent plans for eventual transfer to the Command Agent, or as use files, in which plans consistent with ITM have been developed.[7]

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[7]The development of war plans involves several stages of effort. Initially, use files are developed because of their simplicity, ease of modification, and quickness with which they can be

ITM is the result of the first stages of a five-year development plan for the RSAS approved in June 1991 by the RSAS Steering Group, and subsequently modified in June 1992 by the RSAS Steering Group.[8] However, funding for future JICM development is uncertain, and funding reductions have already led to some diversion from even the modified plan.

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run. Control plans are next developed to begin testing contingencies; they should reflect substantial experience with the use files in determining key branches and sensitivities to be examined. Finally, the control plans are developed into AWPs for more systematic investigation. Because of the development of ITM and changes in the world, JICM 1.0 operates only with use files, although we anticipate working on war plans if future JICM development is funded.

[8]The original and modified plans are documented in unpublished RAND drafts.

Acknowledgments

We are indebted to many people who have contributed to JICM development during the past two years. In particular, Mr. Andrew Marshall, the Director of Net Assessment, has provided key support and guidance on pursuing future of warfare issues, for which we are most grateful. Commander Robert Wilde, U.S. Navy (USN), and Colonel Jeff Barnett, U.S. Air Force (USAF), have assisted in many areas as the JICM Technical Monitors in the Office of the Director of Net Assessment. Some of the others who have provided valuable assistance in JICM development are Enrique Alvarez (Naval Postgraduate School); Professor Charles Bartlett (U.S. Naval War College); Professor Norman Channell (Naval Postgraduate School); Robert Chicchi (U.S. Army War College); Jo Cole (Defense Intelligence Agency [DIA]/ODB); Lieutenant Colonel David Cook, U.S. Army (USA) (DIA); Major Scott Dorff, USAF (USAF/XO, OSD); John Elliott (U.S. Army Concepts Analysis Agency); Commander Robert Filanowicz, USN (U.S. Naval War College); Julie Fuller (U.S. Army Concepts Analysis Agency); Lieutenant Colonel Charles Gettig, USA (U.S. Army War College); Lieutenant Commander Michael Harrell, USN (U.S. Naval War College); Mark Harstad (PACOM); O. E. (Bud) Hay (U.S. Naval War College); Lloyd Hoffman (DIA); Robert I'Anson (DIA/ODB); Major Bill Johnson, USAF (Air University); Kenneth Lavoie (Air University); Lieutenant Colonel David Lee, USAF (National Defense University); Captain Scott Mathes, USAF (Air University); Captain Kevin McClung, USA (U.S. Army War College); Colonel Charles Miller, USAF (USAF/XO); Colonel Joseph Mitchell, U.S. Marine Corps (USMC) (MCWAC); Lieutenant Colonel Donna Mooney, USAF (U.S. Forces Korea, TRANSCOM); Michael Moore (Hq DAMO); Lieutenant Colonel Mike Murdock, USMC (USMC/Plans); Colonel Jeff Pace, USAF (National Defense University); Dmitry Ponomareff (OSD/NA); Dr. Lauri Rohn (OSD/PA&E); John Roley (U.S. Army War College); Colonel Gabriel Rouquie, USA (Hq EUCOM); Dr. Patricia Sanders (OSD/PA&E); Colonel Edward Shirron, USA (National War College); Lieutenant Karen Struble, USN (U.S. Naval War College); Major Terry Tullia, USAF (Air University); Colonel Jerry Wilkes, USA (U.S. Army War College); and Richard Wright (National Defense University). Many others have made important suggestions and provided helpful inputs.

A number of RAND personnel besides the authors have assisted in JICM development. Their names are included in footnotes at the beginning of each section. The authors appreciate the effort of Paul Davis, who led the RSAS effort

for many years and continues to provide valued guidance. Robert Howe reviewed an earlier draft and provided valuable recommendations.

The authors assume responsibility for any shortcomings in this documentation or the JICM itself.

Acronyms and Abbreviations

AAW	Anti-air warfare
ADA	Air-defense artillery
AFCENT	Allied Forces, Central Europe
AFNORTH	Allied Forces, Northern Europe
AFSOUTH	Allied Forces, Southern Europe
AI	Air interdiction
AMRAAM	Advanced medium-range air-to-air missile
AOA	Amphibious Objective Area
APC	Armored personnel carrier
ARV	Armored reconnaissance vehicle
ASW	Antisubmarine warfare
ATACMS	Army Tactical Missile System
ATW	Anti-tank weapon
AUFS	Apple UNIX File System
AWACS	Advanced Warning and Control System
BAI	Battlefield air interdiction
CADEM	Calibrated Differential Equation Methodology
CAS	Close air support
C3	Command, control, and communications
C3I	Command, control, communications, and intelligence
C-Day	Start of deployment
CFCK	Combined Forces Command, Korea
CFE	Conventional Forces in Europe
CINC	Commander in chief
CONUS	Continental United States
CORBA	Common Object Request Broker Architecture
COSE	Common Open System Environment
DCA	Defensive counter-air
D-Day	War start
DIA	Defense Intelligence Agency
DMZ	Demilitarized zone
DOE	Distributed Objects Everywhere
ECM	Electronic countermeasures
EMT	Equivalent megatons
FAC	Forward air controller
FLOT	Forward line of own troops

FSCL	Fire Support Coordination Line
FSS	Fast sealift ships
FTP	File transfer protocol
GMT	Greenwich Mean Time
HARM	High-speed anti-radiation missile
HET	Heavy-equipment transporter
ICBM	Intercontinental ballistic missile
ID	Infantry division
IFV	Infantry fighting vehicle
JLASS	The Joint Land, Aerospace, and Sea Simulation
JSTARS	Joint Surveillance Target Attack Radar System
KPH	Kilometers per hour
LMSR	Large, medium-speed RoRo
LOC	Line of communication
LRA	Long-range artillery
MAGTF	Marine Air-Ground Task Force
MDS	Mission designator series
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MLRS	Multiple-launch rocket systems
MPS	Maritime prepositioning ship
MRC	Major regional contingency
MRL	Multiple rocket launchers
NDU	National Defense University
NEF	Naval Expeditionary Force
NPS	Naval Postgraduate School
OCA	Offensive counter-air
OIR	Optical infrared
OMG	Operational maneuver group
OS	Operating system
PAA	Primary aircraft authorization
POL	Petroleum, oil, and lubricants
POMCUS	Positioning of materiel to unit configured sets
QRA	Quick-reaction alert
RAW	Radar and warning
RoRo	Roll-on/roll-off
RPG	Rocket-propelled grenade
SACEUR	Supreme Allied Commander, Europe
SAM	Surface-to-air missile
SEAD	Suppression of enemy air defenses

SOF	Special operations forces
SPOD	Seaport of debarkation
SPOE	Seaport of embarkation
SSBN	Subsurface nuclear ballistic [ship]
SSM	Surface-to-surface missile
SVR4	System V Release 4
TAIR1	Air-delivered nuclear weapon
TASM	Conventional antiship missile
TD	Towed
TLAM	Theater land-attack missile (sea-launched nuclear cruise missile)
TLC/NLC	Theater-level combat/nonlinear combat
TLI	Transport Layer Interface
TTY	Teletype writer
TUS	The U.S. [concept of operations]
USAF	U.S. Air Force
WRM	War reserve materiel

1. Introduction

Bruce Bennett

The Joint Integrated Contingency Model (JICM) is a game-structured simulation of major regional contingencies and higher-level conflicts, covering strategic mobility, regional conventional and nuclear warfare in multiple theaters, naval warfare, and strategic nuclear warfare.[1] The JICM has been developed as part of a multiyear project attempting to provide improved tools for strategy analysis.

In the past few years, the conditions of potential conflict have changed substantially, and many more changes appear to be developing. With these changes, the tools used for modeling and analysis of warfare must change as well. To achieve the objective of accommodating the changes, we have made a major element of JICM research over the past three years the analysis of the future of warfare and the implications of that future on warfare modeling.[2]

The JICM spans the interests of the analytic and the war gaming communities. It provides decision models to aid in war gaming and/or analysis or to even assume the role of certain players, as well as models of military operations and combat. In comparison with traditional military models, which often focus on predicting combat outcomes with some degree of (generally spurious) precision, the JICM provides more of a laboratory for the study of military strategy and operations,[3] a laboratory in which the evaluation of alternative strategies and operations is in terms of the robustness of outcomes across the inherent range of uncertainty in scenarios, performance factors, and "rules of war." Designed primarily for analytic purposes, the JICM and its predecessor, the RAND Strategic Assessment System (RSAS), have also been used for training, war gaming, and other requirements.

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[1]The JICM was originally developed as the RAND Strategy Assessment System (RSAS). Starting in FY92, a post–Cold War redesign of the RSAS, which we named the JICM, was carried out and implemented.

[2]Part of our work in this area has been documented in Bruce W. Bennett, Sam Gardiner, Daniel B. Fox, and Nicholas K. J. Witney, *Theater Analysis and Modeling in an Era of Uncertainty: The Present and Future of Warfare*, RAND, MR-380-NA, 1994.

[3]This is not to say that the JICM is any less accurate than other theater-level models, but rather that the inherently large uncertainties of theater-level conflict are recognized as an explicit part of the JICM design and that provision is made for the analyst to assess the effect of uncertain inputs on conflict outcomes. JICM users are also encouraged to avoid stating results in ways inconsistent with the underlying uncertainties; for example, an analyst would be encouraged to avoid stating loss rates to three significant digits when the uncertainties make the stated rates true within a range of 50 percent or so.

This document describes how JICM 1.0, initially released in late 1993, varies from its predecessor, the RSAS 4.6 version, released in late 1991. The few parts of the JICM that have not changed over the past two years are therefore not dealt with herein. Readers interested in these components should refer to the *RSAS 4.6 Summary*.[4]

The remainder of this section describes the basic structure of the JICM, highlights changes in JICM 1.0, and describes how the JICM has been implemented on Sun computers. Section 2 provides a short description of the perspective on the future of warfare that we have developed as a background for JICM development. Section 3 explains the geographic representation made in JICM 1.0. Sections 4 through 7 describe the various components of the JICM Integrated Theater Model (ITM). These sections are oriented to helping users learn how to apply ITM. Section 8 summarizes changes made to the JICM system software, and Section 9 shows some of the advances in the JICM that are intended to make JICM easier to use. Attached as appendices are (A) a list of JICM publications, (B) a glossary of JICM terms, and (C) a discussion of how the JICM should be used for analysis and gaming.

JICM Components

The components of the JICM can be viewed either functionally or from the perspective of the JICM software implementation. The two approaches are presented and compared here. Throughout this report, the normal approach taken is to view components functionally.

Functional Components

Functionally, JICM 1.0 is made up of three major components:

The Command and Government Agents. The Command and Government Agents are the part of the JICM that records prospective military and national operations plans. Each government may use the generic procedures for mobilizing, alerting, and training forces, or it may employ rules tailored for its own national forces (especially if partial or selective mobilizations are required). Governments may also establish their own procedures for employing nuclear forces under national control. The Command Agent reflects either military commands that may operate forces belonging to a single nation or a coalition of

[4]Bruce W. Bennett et al., *RSAS 4.6 Summary*, RAND, N-3534-NA, 1992.

forces usually operating in a specific regional contingency.[5] Military operations are almost always planned and executed by commands in the JICM. These plans can then be augmented by JICM control plans, which can be developed and later changed more quickly. JICM 1.0 includes only the beginning of plans (in the form of use files) for conflicts in Korea, Turkey, Eastern Europe (Poland, Ukraine, Belarus, and Russia), and Taiwan.[6]

CAMPAIGN. The JICM models of military operations (such as deployments) and combat adjudication have traditionally been referred to as the Force Agent, or the CAMPAIGN model. In the RSAS, CAMPAIGN included two models of theater operations: (1) the Main Theater model (CAMPAIGN-MT), which covered Central Europe and Korea, and (2) the Alternate Theater model (CAMPAIGN-ALT), which covered Northern Europe, Southern Europe, the Persian Gulf, and the Middle East. In JICM, these two models have been replaced by ITM. In addition to ITM, the JICM includes models of logistics and mobility (as described in Section 7), models of naval warfare,[7] and models of nuclear force operations (including damage assessment and strategic command, control, communications, and intelligence).[8] JICM 1.0 includes orders of battle for nearly 70 major countries worldwide, and baseline values are provided for all JICM parameters.[9]

System Software. A wide range of computer system software supports the JICM. Changes to the system software are described in Section 8.[10]

Implementation Components

From the perspective of implementation, the JICM is divided into two program components, JICM-A and JICM-C, and a series of supporting tools. The World

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[5]The Government and Command Agents are documented in Section 5 of Bruce W. Bennett et al., *RSAS 4.6 Summary*, 1992. They have not been updated to correspond to ITM and thus are retained, for now, primarily as placeholders until the logic in the use files currently designed to reflect theater plans for ITM can be updated into this part of the JICM.

[6]One of the products of the ongoing JICM verification, validation, and accreditation (VV&A) effort is an improved set of plans for Korea and the Persian Gulf.

[7]Other than the changes in geography documented in Section 3 and of deployment procedures documented in Section 7, the naval models have not changed greatly since RSAS 4.6 and are documented in Section 9 of Bruce W. Bennett et al., *RSAS 4.6 Summary*, 1992.

[8]The nuclear models have not changed greatly since RSAS 4.6 and are documented in Section 11 of Bruce W. Bennett et al., *RSAS 4.6 Summary*, 1992.

[9]Preparing the JICM data bases is a difficult and intensive task. The author acknowledges the efforts of John Bordeaux, Arthur Bullock, Carl Jones, Barry Wilson, and John Schrader.

[10]The various elements of JICM system software are documented in Sections 12 and 13 of Bruce W. Bennett et al., *RSAS 4.6 Summary*, 1992. The new JICM Map graphics package is described in Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, RAND, MR-122-NA, 1993. An updated description of this graphics system as used in JICM 1.0 exists as an unpublished RAND draft.

Situation Data Set (WSDS), which supports the JICM, is similarly divided into two parts, WSDS-A and WSDS-C.

JICM-A. The JICM-A is largely the decision model part of the JICM and is implemented in pure RAND-ABEL®.[11] It includes the Government and Command Agents' decision models. It is supported by the WSDS-A data base.

JICM-C. The JICM-C is the part of the JICM written directly in the C programming language, although in JICM 1.0 it contains a considerable amount of C-ABEL code (functions written in RAND-ABEL but not tied to the JICM-A data dictionary and thus directly transferable to the C language for compilation with the rest of the C code). The JICM-C includes all of CAMPAIGN. In a stand-alone mode, the JICM-C program is named camper and can be run without any connection to the JICM-A. The WSDS-C is the data set for the JICM-C and actually consists of two parts: (1) those items fixed throughout any run (such as the names of specific forces), referred to as the WSDS.Fix, and (2) those items that may vary in a run (such as parameters), referred to as the WSDS.F.

Supporting Tools. A series of supporting tools can be used as separate processes with the JICM, as listed in Table 1.1. Normally, the JICM may run without these processes (with the exception of CAMPAIGN Menu Tool [CMENT] or the corresponding Force window), although they may be called at any time during a run.[12]

Comparing JICM Functions and Implementation

Table 1.1 compares the JICM functions with the JICM components as implemented. Note that only the major functional entities are included in this table.[13]

Themes in JICM 1.0

The principal JICM effort in FY92 and FY93 has been the development of ITM. In concept, ITM involves a merger of the two former RSAS theater models, CAMPAIGN-MT and CAMPAIGN-ALT, so that JICM users need to learn only a

[11]RAND-ABEL is a registered trademark of RAND.

[12]If, however, camper is instructed to communicate with JICM Map before the latter has been initialized, later attempts to initiate JICM Map and have it function properly with that copy of camper will be unsuccessful. In such a case, the user needs to restart camper (which could be done from a data base saved from the existing camper) and run it with JICM Map initialized.

[13]The author appreciates the software integration and configuration control efforts of Arthur Bullock, Carl Jones, Robert Weissler, and Barry Wilson.

Table 1.1

Comparison of JICM Functions and Implementation

Functional Component	Implementation Element: JICM-A	JICM-C	Supporting Tools
Command & Government Agents	Military commands Governments National commands		
CAMPAIGN		ITM Naval ops & combat Logistics & Mobility Strategic models JICM-C Interface	Input Processor Retargeter
System Software	System Monitor		RAND-ABEL Compiler Interpreter C-ABEL compiler Hierarchy Tool Graph Tool JICM Map CMENT

single, simplified theater model to consider theater conflict anywhere in the world. The design of ITM takes advantage of the strengths of both CAMPAIGN-MT and CAMPAIGN-ALT, but then goes beyond them, using our research into the future of warfare and our experience in model use and gaming. Principal enhancements included in ITM are as follows:

- Development of an integrated land geography and networks. Places are now defined and are connected with links that form the basis for administrative and combat movements. Locations are now defined in terms of places rather than by region, as was done in the RSAS (see Section 3 for details).
- Provision for full operational maneuver across the land network. Both CAMPAIGN-MT and CAMPAIGN-ALT were limited to combat movements along a "piston"; ITM allows movement in any direction along any part of the network, and defines combat interactions whenever opposing forces come into contact in any configuration (frontal contact, flank contacts, rear contacts, and internal—security—contacts). JICM commands (often reflecting real-world corps) are the key entities that maneuver over the network, although individual forces outside the purview of their command can also be involved in contacts.
- Enhancement of battle definitions, which include factors such as the various components of the Situational Force Scoring methodology (posture, terrain,

force shortages, and casualty distribution), separate adjudication of artillery fires in a weapon-on-weapon framework, artillery fire suppression, and the effects of various other fires (air, attack helicopters, and long-range artillery such as the Army Tactical Missile System [ATACMS]). Battles are constrained by the *logistics tail of the attacker* (i.e., the notional representation of all logistics support, which trails the combat force) and the efforts of both attacker and defender to move massed forces along limited lines of communication. Battles may conclude in a failed assault, a breakthrough, or a defender's withdrawal; battles are not assumed to be continuous (in contrast to some theater models that assume continuous assaults of weeks' duration).

- Reorganization of air tasking in a theater to follow the basic pattern of an air tasking order (ATO). The ATO is derived from guidance on use of multirole aircraft, division of air-to-air sorties and air-to-ground sorties into mission areas, packaging of aircraft to perform specific missions,[14] timing of sorties in each mission category, and allocation of mission sorties to specific targets. The development of the ATO is done in C-ABEL code, enabling users to make changes in procedures, if desired. The product of the ITM ATO planning process is a list of aircraft packages (and the aircraft within each package) designating the activity and timing of the package, as illustrated in Figure 1.1. To better parallel the real-world ATO, cruise missiles (e.g., theater land-attack missiles [TLAMs]) and other systems can be included in the ATO. See Section 5 for details.
- Execution of the ATO by package, and adjudication[15] of air combat results to recognize the contributions of each component of the package, including suppression of enemy defenses (SEAD) aircraft, escorts, and mission aircraft.
- Development of an amphibious operations model integrated with ITM. It includes adding amphibious lift to the JICM ship data base, using this lift to move selected amphibious (Marine) units, designating beach areas for assaults, providing logic associated with amphibious assaults, and making a transition from the amphibious assault to the ITM combat network.
- Development of a new map graphics package called JICM Map. JICM Map is closely tied to ITM, allowing the user to observe combat interactions on a map, as shown for the central part of Korea around the Chorwon Valley in Figure 1.2; the user may touch map symbols to obtain greater detail on the

[14]*Packaging* is the combining of aircraft assigned differing missions into a single flight or group to achieve the synergies of the separate missions.

[15]*Adjudication* is an assessment, given inputs, of what the outcome will be.

7USAF ATOs for Period 2:

ID	Squadron	Aircraft	Mission	#	Target
3	8-TFW/1-TFS	A-16	BAI	4	KS_CC>>4-Corps/1-ID
	8-TFW/2-TFS	F-16C	Escort	1	
	8-TFW/1-TFS	A-16	SEAD	1	
4	8-TFW/1-TFS	A-16	BAI	4	KS_5C>>5-Corps/1-MXD
	8-TFW/2-TFS	F-16C	Escort	1	
	8-TFW/1-TFS	A-16	SEAD	1	
21	8-TFW/1-TFS	A-16	OCA	4	Pukchang Air Base
	8-TFW/2-TFS	F-16C	Escort	2	
	8-TFW/1-TFS	A-16	SEAD	1	
33	8-TFW/11-TFS	F-16C	AI	2	12-Corps/1-MXB
	8-TFW/12-TFS	F-16C	Escort	1	
	.....				

Figure 1.1—Sample Packages from the ITM ATO

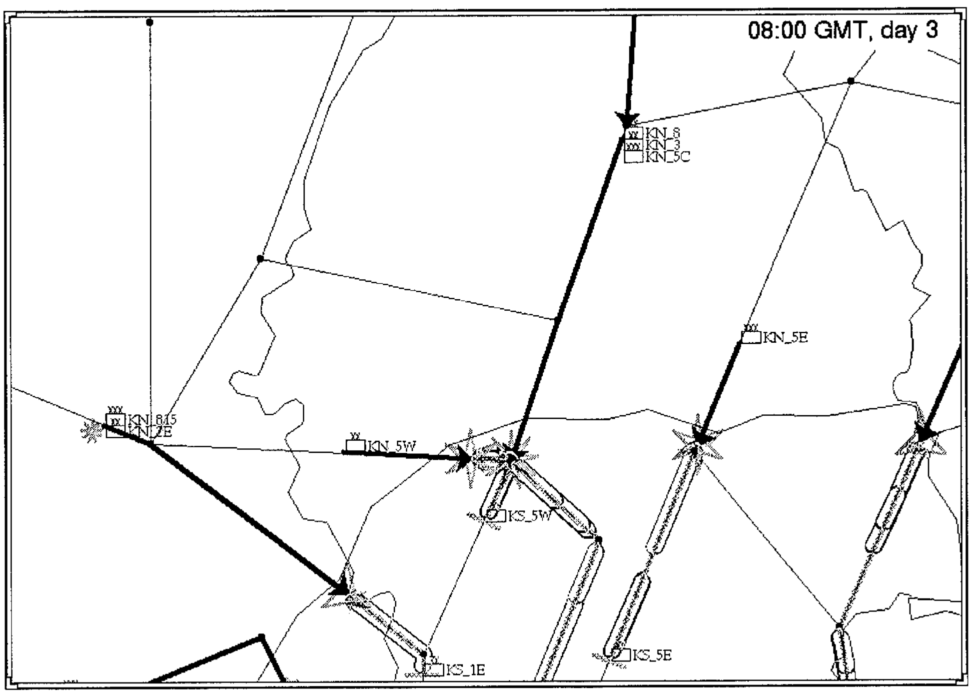

Figure 1.2—State of the Central Korean Battlefield, with Multiple Battles

conflict situations, an example of which is shown in Figure 1.3.[16] All graphics inputs come directly from CAMPAIGN (rather than from separate, static files, as was done in the RSAS) and, thus, reflect the true current state of the simulation; the new Sun ToolTalk utility is used as the basic communications interface by JICM Map.

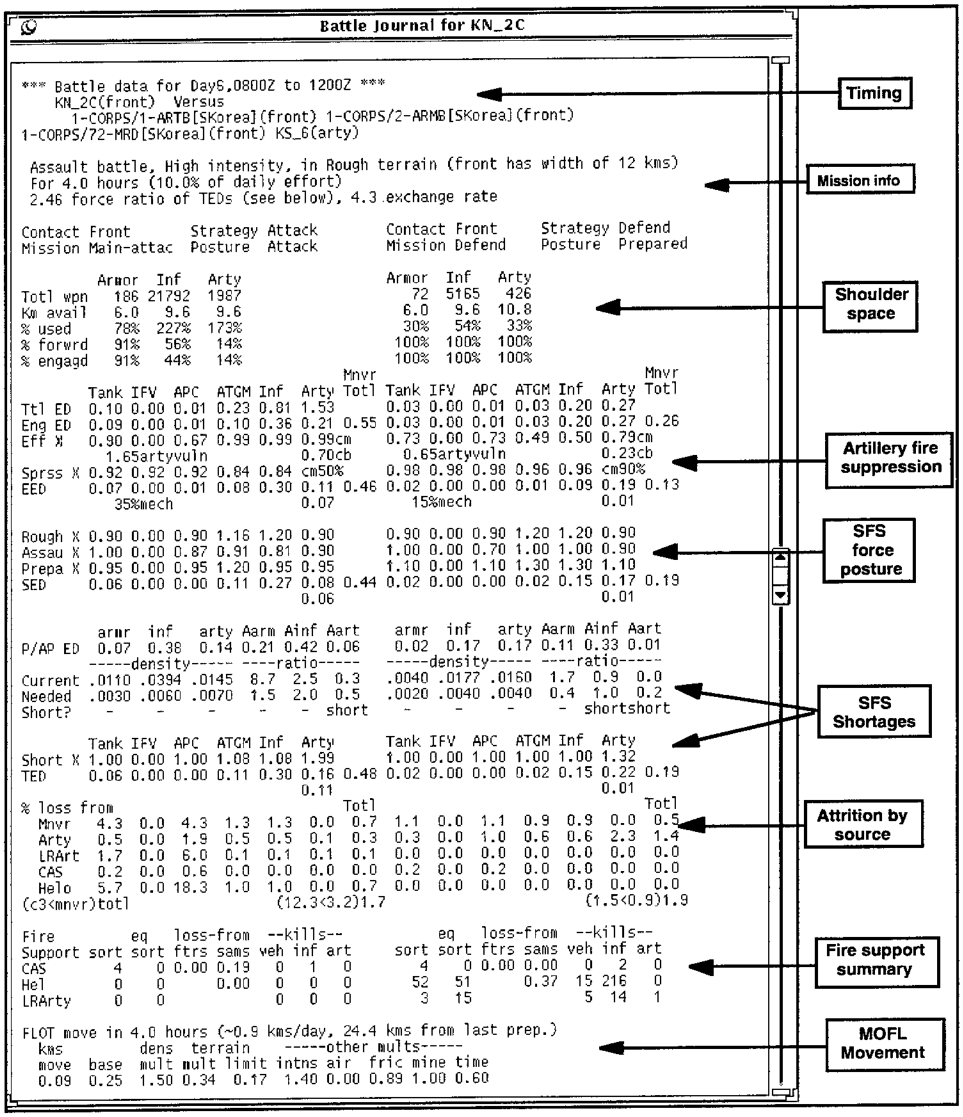

Figure 1.3—The Battle Display for the Chorwon Valley

16 JICM Map is documented in Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, 1993. An updated description of this graphics system as used in JICM 1.0 exists as an unpublished RAND draft.

- Enhancement of the RAND-ABEL language to allow for a full range of data structures and other variable formats. In turn, these enhancements facilitated the development of C-ABEL, a version of RAND-ABEL that is thoroughly integrated with the C language programs of CAMPAIGN, without connection to the WSDS-A or other parts of the traditional RAND-ABEL environment (including the Interpreter). ITM was developed using the general philosophy that substantive parts of ITM should be coded in C-ABEL to make them more transparent and easier to change, whereas bookkeeping and other difficult aspects of ITM should be done in C to make them more efficient and hide them from the analyst, discouraging attempts to change code that might lead to unexpected errors and other problems. The user may also define control plan logic and incorporate it into C-ABEL.

The other major issues addressed in JICM 1.0 are as follows:

- JICM future of warfare work has clarified the character of scenarios and warfare environments that should be examined by a model such as the JICM. In particular, a much broader spectrum of conflict conditions needs to be considered, and a clear rationale developed, for various kinds of opposition threats. We refer to the threat space for a given future contingency, and characterize a series of potentially asymmetrical battles as part of a future conflict (see Section 2). The resulting countercapabilities framework is being developed to aid us in prioritizing model developments.
- We observe that in major regional contingencies (MRCs), potential opponents may prefer to engage the United States in short wars, before the United States can fully deploy its military forces into a theater. This observation motivates more attention to shorter-warning conditions and to the need for short-term force viability when troops are deployed into a theater, since an opponent may oppose U.S. deployments.
- We have paid further attention to developing an environment in which the use of nuclear weapons in a regional conflict can be properly evaluated, reviewing regional nuclear forces and weapon effects, developing mobile missile systems (both offensive and defensive), and improving the representation of anti-ballistic missiles. Missile units are displayed on JICM Map. We have also added the option for simulating the effects of chemical weapons used against civilian populations.
- All parameters (for both C code and C-ABEL code) are defined using the same parameter interface, which is fully documented. New parameter, order, and display documentation has been developed and can be easily

converted into formatted appendices for hard-copy documentation. In addition, a new standard for parameter references was developed.

- An attacker's frontal mass along a line of advance is now limited by the rate of advance of the command and the ability of the road network to sustain that advance, leading to pauses in attacks as the attacking forces are preparing for an assault or to the crumbling and overrunning of a defense unable to withdraw sufficiently rapidly.
- Positional commands allow the analyst to define a defensive posture with only very limited mobility. In relatively static defensive-line cases, these lines can be readily defined and the character of the resulting defense simulated.
- A tactical command, control, communications, and intelligence (C3I) model was added for ground force operations. The model adjusts the effectiveness of ground force defenders according to the relative C3I superiority of the attacker.[17]
- Long-range artillery can now be defined to strike targets other than the immediately opposing ground forces. Munitions and their effects can be varied and fires planned.
- Artillery can be fired against approaching opponents, even when opponents are still out of contact (for example, across the Korean demilitarized zone).
- Terrain segments may be mined to impede the flow of opposing forces and impose attrition upon them. These minefields can be defined in addition to the traditional designation of prepared defensive positions.
- In the RSAS, attack helicopters flew only in support of the command to which they were assigned. In ITM, attack helicopters are able to support any ground force command within helicopter range of their location, or can strike any enemy ground force target within helicopter range. Ground force missions may be established for the helicopters in any unit.
- Some of the operating characteristics of mechanized versus armored forces are explicitly captured, including relative movement rates, the effect of terrain on movement rates, and the vulnerability of the forces to opposing artillery fire.
- ITM follows the operations of SEAD aircraft, the Advanced Warning and Control System (AWACS), and the Joint Surveillance Target Attack Radar

[17]This model has been briefed extensively to the RSAS Working Group and is documented in Bruce Bennett, "Ground Combat C3I Effects," *RSAS Newsletter*, January 1992.

System (JSTARS). Although its modeling in each case is simple, these aircraft do fly and their effects can be monitored in an analysis.

- Commands used to support ITM are developed hierarchically, supporting both echelonment and parameter definition. Many parameters are defined at the command level, which allows changes to be made for multiple lower-level commands by doing the change for a higher-level command.
- Port representation is enhanced to five classes of berths (deep roll-on/roll-off [RoRo]; RoRo; container; petroleum, oil, and lubricants [POL]; other). Capacity constraints by type of berth are specified, as are times for loading and unloading. Units arriving in a port require time to form up after unloading.
- Deployments by sealift can be stopped, slowed, or delayed.
- Air, ground, and missile forces can be created on-line using *scripts* (instructions to the model to change data base values).
- Air, ground, naval, and missile forces can be moved to new locations, using scripts.
- Theater logic (geography, parameters, command structure, and initial operations plans) has been developed for Korea; the Persian Gulf; Turkey; and for the area including Poland, the Ukraine, Belarus, and Russia.
- Seaboxes have been defined as a geographic overlay for the JICM ocean regions, based on the patrol boxes of the RSAS. Ships are now routed across these seaboxes so that patrols can be done against transiting ships. The patrol area concept now operates as an aggregate of (one or more) seaboxes.
- The JICM system software has been standardized to operate on Sun-4 computers, and to operate under the X Windows standard. These changes significantly simplify the old software that supported both Sun-3 and Sun-4 operations, under both SunView and X Windows.
- The new system software environment does away with the former Listen interface, which used to cause the Force window to fail intermittently without explanation. Camper now is more in control of the course of the simulation, and the new Sun ToolTalk package has become the standard for interprocess communication.
- Many of the order of battle data structures have been transferred from fixed storage to the JICM "heap," which means that computer memory is reserved only for those units defined by the user (however many that may be). Options have been added to limit the number of countries included in any given data base to keep the data base small, efficient, and understandable.

- Conventions have been established to bring greater regularity to the names of ground forces in the JICM. Names now include a designation of the type and size of unit, done in a consistent manner (this change was part of the ITM design).
- To keep the JICM data base maintenance within the range of effort feasible under declining JICM budgets, a list of countries was developed, shown in Table 1.2, for which order of battle data will be maintained. Countries not on this list will not be included in the JICM data base, but they may be added by users. The list reflects all areas where major regional contingencies appear possible.[18]
- JICM orders of battle have been updated to 1993 in many cases (based on inputs from the Defense Intelligence Agency [DIA]), and projected data for the year 2000 have been provided in some cases (based on Global 92 assumptions).
- The ground force data for most countries have been expanded to 14 equipment categories and scored according to the JICM scoring system,

Table 1.2

Countries Maintained in the JICM 1.0 Data Base

Region (Number)	Countries Involved			
Asia (13)	Australia India Indonesia Japan	Malaysia North Korea Pakistan Philippines	PRC Singapore South Korea Taiwan	Vietnam
Middle East (25)	Algeria Armenia Azerbaijan Bahrain Egypt Georgia Iran	Iraq Israel Jordan Kazakhstan Kuwait Kyrgyzstan	Libya Oman Qatar Saudi Arabia Syria Tajikistan	Tunisia Turkey Turkmen UAE Uzbekistan Yemen
Europe (23)	Belarus Belgium Czech Denmark Estonia Finland	France Germany Greece Hungary Italy Latvia	Lithuania Netherlands Norway Poland Russia Slovakia	Spain Sweden Turkey UK Ukraine
Americas (3)	Canada	Cuba	U.S.	

[18]Note that areas such as Bosnia, Croatia, and Serbia are not included in this list, despite the potential importance of combat there. Their omission reflects our feeling that combat in these areas will not be of the same character as combat in a major regional contingency, and we have not yet progressed to the point where we feel we can adequately model such combat.

which replaces the weapon-effectiveness index/weighted unit value (WEI/WUV) scoring system used in the RSAS.

- Region and government names have been added for the new countries of the former Soviet Union, Yugoslavia, and Czechoslovakia.
- The JICM data base includes a Joint Land, Aerospace, and Sea Simulation (JLASS) case (j98), which shows the forward Republic of Korea (ROK; South Korea) Army units divided, ROKAF locations per student inputs, U.S. forces at base force level (not new projections), and inadequate modernization of Chinese forces (based on information available in late 1992, much of which has changed).
- A number of new JICM data files have been added: navair.sec (for naval aircraft), place.unc (which defines the places and links of the JICM network), and materiel.sec (which includes equipment information for positioning of materiel configured to unit sets [POMCUS], maritime prepositioning ships [MPS], and war reserve materiel). Files theater.sec and zone.sec were deleted in favor of entering theater-specific data with use files placed in the Force-C/D/Env directory. Files laydown.unc and minor.sec were deleted.
- Marine Corps amphibious groups were redone to correspond to the Navy's "Force 2001" briefing, including the Naval Expeditionary Force (NEF) concept of operations.

A number of smaller changes were also completed in JICM 1.0. Moreover, efforts have continued to identify and correct bugs found in the JICM, and, given the size and complexity of the JICM code, such efforts can be expected to continue for some time. Specific efforts included the following:

- As the armored vehicles in a unit are destroyed, the opponent achieves decreasing returns with its supporting fires. In implementation, this is done by having the supporting fires target one-half of the already-killed armored vehicles in a unit.
- A river terrain type was added to the Situational Force Scoring methodology; it allows for a simplified simulation of river crossings.
- The relative effectiveness and vulnerability of attack helicopters operating at night are defined through JICM parameters.
- Ground forces that make administrative advances toward an opposing force (because the opposing force has moved to a position that covers the intended line of advance) will be rerouted to their intended destination.

- Decreasing returns have been added to the formulation of combat movements, which now approach a maximum movement rate asymptotically.
- The fire suppression effect of artillery is simulated.
- Detailed logs allow for easy analysis of the effects of various kinds of fire support.
- The effect of artillery shelters in border areas can be simulated.
- The effect of supporting fires on the movement rate of an attacker has been made a function of the C3I system of the defender, reflecting the defender's relative ability to get close air support aircraft and other such fires committed against areas where key problems are developing in the defense.
- Default aircraft packages were developed for the range of ITM air missions, and were reviewed and adjusted with the Air University.
- An option has been provided to define aircraft packaging for differing environments. For example, the user might define a high-threat environment with many escorts in the packaging, and a low-threat environment with few escorts. Then a single parameter setting can be used to instruct the ATO planner to shift from one set of packages to the other.
- Ground and air force supply models are operational for munitions and some other classes of supply.
- A notional logistics tail may be defined as a tether on offensive operations.
- The consumption of air-to-air munitions was made a function of the aircraft losses (aircraft that are killed take with them at least some of their munitions) and aircraft kills (based on an expected number of munitions used per kill).
- A cease-fire order has been provided to terminate hostilities (either permanently or temporarily) in a theater.
- New displays were added for battles (to include out-of-contact operations, unopposed advances, and summary details), paths of ground forces, ground force history, air tasking orders, missile forces, long-range artillery tasking, attack helicopter tasking, permissions, and places.
- The find display was enhanced to show the full range of effectiveness factors that apply to each force.
- A new display standard was developed, in which many displays get more detail. The displays that have this added detail are designated in the "display" command listing with the first letter capitalized.
- New procedures were developed for routing naval forces, to allow for coordinated and/or controlled deployments.

- Procedures were added to CAMPAIGN to automatically update JICM Map on a regular basis without running into possible data inconsistencies that can happen as CAMPAIGN advances.
- The game time was added to JICM Map.
- Sea routes can be displayed on JICM Map.
- A distance calculator was added to JICM Map, which simplifies the process of determining the tactical or operational length of a given border.
- The CAMPAIGN "pause" command was enhanced with the addition of a "break" response, which terminates use file processing, and an "ignore" response, which overrides subsequent "pause" instructions in a use file.
- The time reference in the JICM can now be shifted to refer to start of deployment (C-Day), war start (D-Day), or other reference times.

Computer Issues

The JICM continues to run on Sun Microsystems computers. It is currently operational on any of the Sun-4–family of systems under Sun OS 4.1.3. RAND does not have experience with all the new equipment Sun is fielding but anticipates only modest difficulties, at most, in making the transition to such equipment (and RAND is committed to that effort).

For JICM 1.0, RAND is recommending the use of Sun-4s with 16 MB of main memory and at least 500 MB of disk space for a stand-alone system (plus another 200 MB for each added system). JICM 1.0 is designed to be operated under the X Windows/OpenWindows interface. JICM 1.0 also requires OpenWindows 3.0 to support the interprocess communications package, ToolTalk.

The JICM is written in the C programming language and in the RAND-ABEL language, which compiles into C. The size of the various program parts is given in Table 1.3, for the previous RSAS 4.0 and RSAS 4.6, and for JICM 1.0, including comment lines and blank lines within the code. The comparison is useful—clearly, we have significantly reduced the size of the JICM-A and other JICM parts.

This information is provided, in part, to make it clear that the JICM is a relatively complex computer code, for which changes must be made with care and understanding. For analysts, there is no requirement to gain familiarity with the supporting source code (for example, the analyst does not have to learn the programming behind the graphics programs); moreover, the JICM is highly

Table 1.3

The Size of the JICM

Item	Number of Lines: RSAS 4.0	RSAS 4.6	JICM 1.0
Source Code:			
JICM-A (AWPs, CAMPAIGN-ALT)	200,000	80,000	37,000
JICM-C	160,000	175,000	185,000
C-ABEL	—	—	11,000
CAMPAIGN support	67,000	75,000	40,000
Other (e.g., graphics)	240,000	300,000	80,000
RAND-ABEL language	80,000	80,000	80,000
Shell scripts	6,000	6,000	3,000
Total Source Code:	833,000	716,000	436,000
Other Materials:			
CAMPAIGN data bases	50,000	61,000	66,000
On-line documentation	70,000	84,000	48,000
Data Editor	35,000	10,000	1,000
Total other materials:	155,000	155,000	115,000
GRAND TOTAL	988,000	871,000	551,000

modular, so that to work in any given area, the analyst is required to gain familiarity with only a subset of the entire JICM.

As a reference, Table 1.4 shows the time required to run two JICM scenarios[19] on a SPARC 1 ELC (low-end Sun-4) operating over a network (not having a local disk); thus, these times are likely upward limits compared to what most JICM users should expect with their current system configurations. Actual performance may vary according to the type of Sun and disk used, the number of processes running on the Sun, the load on the network if running on a Sun

Table 1.4

JICM System Performance Comparisons

Scenario	Scenario Days of: Mobilization	Combat	Minutes of Run Time in JICM 1.0
Turkey versus Syria	18	20	3.0
Korea	3	20	2.5

[19]The two scenarios were derived from the Run/Plan directory, use files amphib (for Turkey versus Syria) and korea (for Korea).

network, and other factors. This time reflects only the elapsed time for the Sun to run this scenario and not time spent in development of the scenario or data, analysis of the scenario, or insertion of human play in the scenario. Even so, it is clear that analysis with the JICM will seldom be limited by run times.

2. Initial Observations on the Future of War

Bruce Bennett[1]

A recent RAND report[2] describes many of our findings on the future of warfare and their implications for the analysis and modeling of major regional contingencies. It, in turn, derived part of its material from the November 1992 *RSAS Newsletter*, which included two articles summarizing some of our observations on the future of warfare that are based on our gaming and analytic work over the past two years.[3] The purpose of this section is to summarize the key points of this work, borrowing heavily from parts of the report. In doing so, our focus is on the strategic and operational issues of future wars and warfare that may be associated with major regional contingencies.

Characterizing the Problem

Even before we begin worrying about analyzing future major regional contingencies, we must first recognize the limitations of our existing analytic approaches and models. There appear to be significant differences between how warfare would likely be conducted today in such contingencies and the ways that we analyze and model such warfare. Part of the problem is that historical analysis and modeling have focused almost exclusively on the Central European (Warsaw Pact) case, allowing the characteristics of that case (in terms of force structure, doctrine, operational art, and warfare environment) to dominate analytic techniques and models, whereas the characteristics of other theaters are often very different.[4] But the key problem is the still-immature state of development of the military science on which analysis and modeling are based.

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[1] The author wishes to acknowledge the assistance of Sam Gardiner and Dan Fox in doing the work behind this section. They suggested many insights that are woven into the framework of the material presented here.

[2] Bruce W. Bennett, Sam Gardiner, Daniel B. Fox, and Nicholas K. J. Witney, *Theater Analysis and Modeling in an Era of Uncertainty: The Present and Future of Warfare*, RAND, MR-380-NA, 1994.

[3] Bruce Bennett, "The Future of War—Initial Wargame Observations," *RSAS Newsletter*, November 1992, pp. 2–12; and Sam Gardiner, "It Isn't Clear Ahead, But I Think I Can See the Edges of the Road: The Character of Future Warfare," *RSAS Newsletter*, November 1992, pp. 23–32.

[4] This problem is described in more detail in Bruce W. Bennett, "Flexible Combat Modeling," *Simulation & Gaming*, Vol. 24, No. 2 (Newbury Park, Calif.: Sage Periodicals Press), June 1993.

Military science has a number of inadequacies that are manifested in the following examples. One is the lack of rules to clearly distinguish key phenomena at the operational, as opposed to the tactical, level of warfare.[5] As a very simple example, an individual tank can run at 60 kilometers per hour (KPH) for an extended period of time, a tank company can move at about 25 KPH for most of a day, but a tank division can move at most an average of 5 to 7 KPH sustained over a day. The phenomena that cause these differences are not well quantified, and there has not been systematic identification of the thresholds at which such discontinuities occur.

Another problem in military science is its failure to clearly recognize and define the phenomena that make combat discontinuous, especially at the operational level. The very character of battles and campaigns is determined by discontinuous events, such as breakthroughs, failed attacks, loss of control, and so forth. Many theater-level analyses and models simply ignore these events and assume continuous combat operations; the result is often a simulated course of events that is incredible (e.g., an army mounting a 30-day assault of continuous intensity on a given defensive position).

A third problem with military science is its failure to adequately handle the qualitative factors in warfare. Analysis at the engineering level (one tank firing on another tank, or a flight of aircraft engaging an opposing flight of aircraft) may be able to afford to ignore qualitative, human factors because most of the factors that determine engineering-level combat are physical science–related (e.g., gravity, electrical laws), as suggested in Figure 2.1.[6] However, at the battle or campaign level of analysis, qualitative factors have substantial importance. Indeed, recent conflicts have shown that qualitative factors, such as training, proficiency, doctrine, and force cohesion, can often be more important determinants of outcomes than the quantitative factors, such as force size. But few theater-level analyses or models include procedures for reflecting these factors, and those that do lack the consensus in approach that ought to be the result of a consistent underlying military science.

The treatment of uncertainties is another key shortcoming of existing military science. At the theater level, not only are the qualitative factors uncertain, but many of the relationships between even the quantitative factors are obscure. And yet, theater-level analysis still often strives for single-answer, point solutions rather than describing the range of potential outcomes. This fact reflects, in part,

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[5]This subject is dealt with in more depth in Bruce Bennett and Patrick Allen, "The Discontinuity in Theater Analysis and Modeling," *Military Science & Modeling*, RAND, May 1993.

[6]This figure suggests the magnitude of importance and should not be construed as a rigorous quantification.

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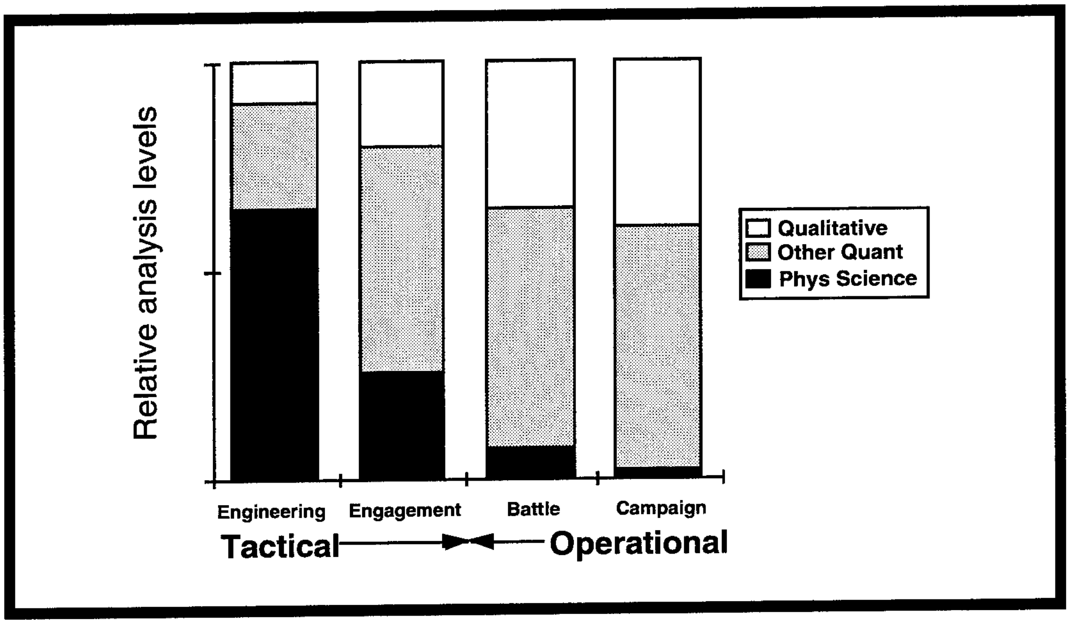

Figure 2.1—Setting the Context

a limitation in the analytic approach for examining warfare: Neither analysts nor decisionmakers seem prepared to work in terms of uncertain outcomes.[7]

Finally, military analysis has for years been dominated by the assumption that most assessments of military capability can use linear methods of aggregation. For example, simple measures of ground force capability involve estimating the value of different weapon systems, then aggregating that value times the number of systems of the given type. The reality is that almost all forms of military operations involve synergisms between differing weapon systems, which are usually referred to as *combined-arms effects*.[8] The community lacks a framework for estimating such synergisms. At the higher level, analysts must also consider the implications of joint and combined operations, which in some cases will yield synergisms (e.g., air forces supporting ground forces), and in other cases will

[7]For example, instead of stating a conflict outcome such as "The opposition forces will be stopped at 12 kilometers from the border," the magnitude of uncertainties in theater-level analysis should require analysts to think in terms of outcomes such as "The opposition forces will likely be stopped before they advance 15 kilometers, unless they are successful in limiting defender response time, or defensive air force effectiveness, or . . ., in which case the attack could reach a depth of at least 80 km," or "Although a reasonable estimate of the campaign outcome is an advance of 20 kilometers, this outcome is totally dominated by the uncertainties, which could lead to outcomes as divergent as an attacker's victory and a defender's victory."

[8]An interesting historical description of one such effect was explored in Sam Gardiner, "The Panoptic Effect of Airpower: Explaining the Multiplier of Air Superiority," *RSAS Newsletter*, January 1992.

involve degradations (e.g., ground forces of one nationality in a coalition not being able to effectively communicate with the neighboring ground forces of another nationality).

We would not want to imply that no efforts have been made to respond to these problem areas. As part of the JICM effort, we have developed procedures for addressing many of these problems. However, the JICM efforts do not yet constitute a military science, despite our efforts to disseminate our work, and other researchers might well adopt different approaches or ignore these factors altogether.

Patterns for the Future

In our analysis of the future of warfare, we have examined a broad range of potential major regional contingencies, as suggested in Figure 2.2 (the medium shading indicates conflicts with clear U.S. potential for involvement; light and dark shadings imply possible U.S. involvement). Some may argue that many of these contingencies are not important to the United States because they are unlikely to involve a major commitment of U.S. forces; yet, the analytic community needs to be able to address them because national decisionmakers may wish to examine potential outcomes and implications for varying degrees of U.S. action in any of these cases.

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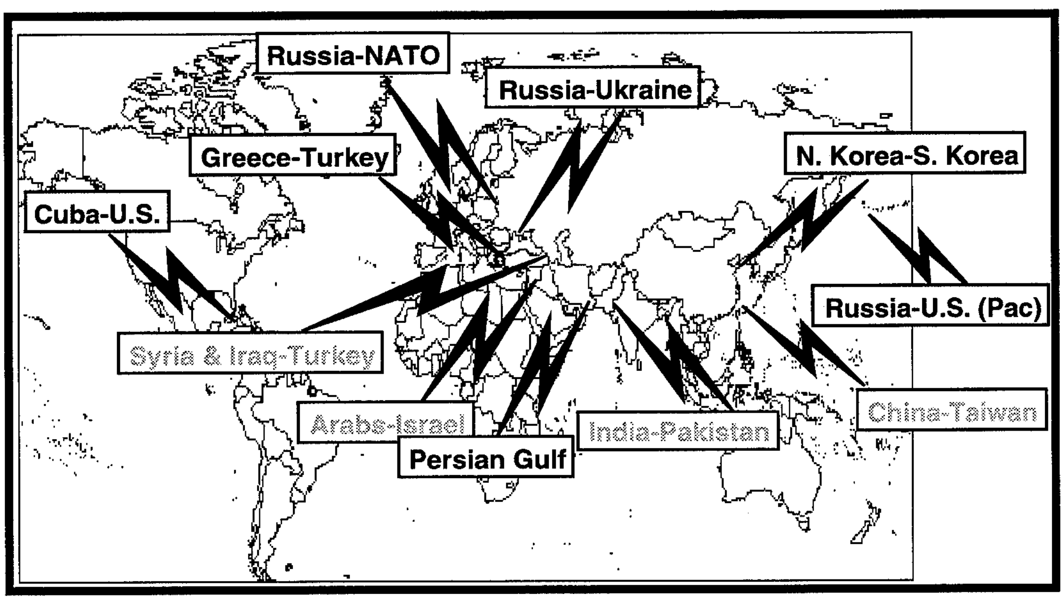

Figure 2.2—Some Contingencies Considered

Using a combination of war gaming and analysis, five lessons have emerged on the ways in which future conflicts potentially involving U.S. forces can be expected to differ from the sort of engagements with Warsaw Pact forces upon which analysis and modeling have historically concentrated:[9]

- Uncertainty in future warfare requires new approaches for analyzing the threat space.
- Warfare environment makes a difference.
- The deployment window for U.S. forces frames future MRCs.
- Asymmetrical battles will likely dominate warfare.
- Third-party nuclear weapons may overshadow many contingencies.

These patterns have substantial implications for analysis and modeling; we will examine each in some detail.

New Approaches Are Required for Analyzing the Threat Space

As we examine prospective major regional contingencies, one clear lesson is that the threats the United States faces are highly uncertain. Even when RAND analysts consider the most basic of issues, such as who will oppose the United States (not just specific countries, but also the possible character of opposition coalitions) and what their objectives will be, we must consider a range of possible alternative conflicts. Issues such as the character of opposition forces and employment concepts are even more uncertain. And we cannot even be certain of the character of the U.S. response to such contingencies.

Historically, much theater-level analysis has used scenarios as a starting point. *Scenarios* (such as those used in *Defense Planning Guidance*) describe a linear development of representative conflict conditions that were perceived as a reasonable basis for analysis because of the limited uncertainty in the character of the conflict that had to be addressed. But in reality the uncertainties are very broad, making any simple set of scenarios inadequate for spanning the plausible circumstances that could be associated with warfare.

The analytic community needs to reconsider its approach to analyzing major regional contingencies and to adopt an approach that better captures the uncertainties faced. An appropriate approach would be to characterize

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[9] As noted earlier, subsequent work has led to some advances in these observations, which we are in the process of documenting separately.

prospective *threat spaces* (the *range* of plausible alternative threats that the United States might face), then to develop "micro-worlds"[10]—each of which would define a part of the threat space in more detail. This approach would focus on capability issues, not on how those capabilities develop. Thus, we would not attempt to explain how prospective opponents might get nuclear weapons, but rather ask whether it makes a difference if they have 2 or 10 or 50. Where clear differences exist, we can then define a specific threat environment and ask questions such as how we might respond to such a threat, how much risk it poses, and whether particular opponents might plausibly be able to create that environment.

The concept of a threat space derives from the U.S. doctrine of employing "decisive force,"[11] and the resulting opposition requirement to negate that force in order to avoid defeat. The opposition may do so by countering the capabilities of U.S. forces or by undermining the will of the United States to become involved or to stay involved in a particular conflict. Because U.S. employment of force will necessarily be graduated (since the United States must incrementally deploy forces to a theater), and because no single counter is likely to completely overcome U.S. forces, opponents will likely attempt to develop a range of counters and apply them in a combined-arms manner. The combined counters applied against U.S. forces constitute the operational element of the resulting threat environment.

The operational component of a threat space (against one leg of the U.S. forces) might be characterized as shown in Figure 2.3. We expect opposition attacks on U.S. air forces because of the importance of these forces. An opponent attempting to overcome U.S. air power might do so by a campaign that focuses on limiting the number of U.S. aircraft in a theater area, reducing the number of sorties that the aircraft in the theater can fly, and/or limiting the effectiveness of sorties against targets. In turn, the number of sorties can be limited by damaging airfields, damaging national logistics (for example, destroying POL distribution and refining capabilities), or timing a conflict to correspond (to the extent controllable) with bad weather. Opposition attacks against U.S. airbases are a particular concern since U.S. air forces will likely be located on a few, dense, high-value targets. To damage airbases, a number of different kinds of attacks

[10]The terminology "micro-worlds" comes from Peter M. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization* (New York: Doubleday/Currency), 1990. The application of micro-worlds to military analysis was explored in Sam Gardiner, "Micro-Worlds: An Alternative to Scenarios," *RSAS Newsletter*, February 1993.

[11]See, for example, the Joint Chiefs of Staff, *1992 Joint Military Net Assessment*, Washington, D.C., Section 2 of which defines the U.S. national military strategy.

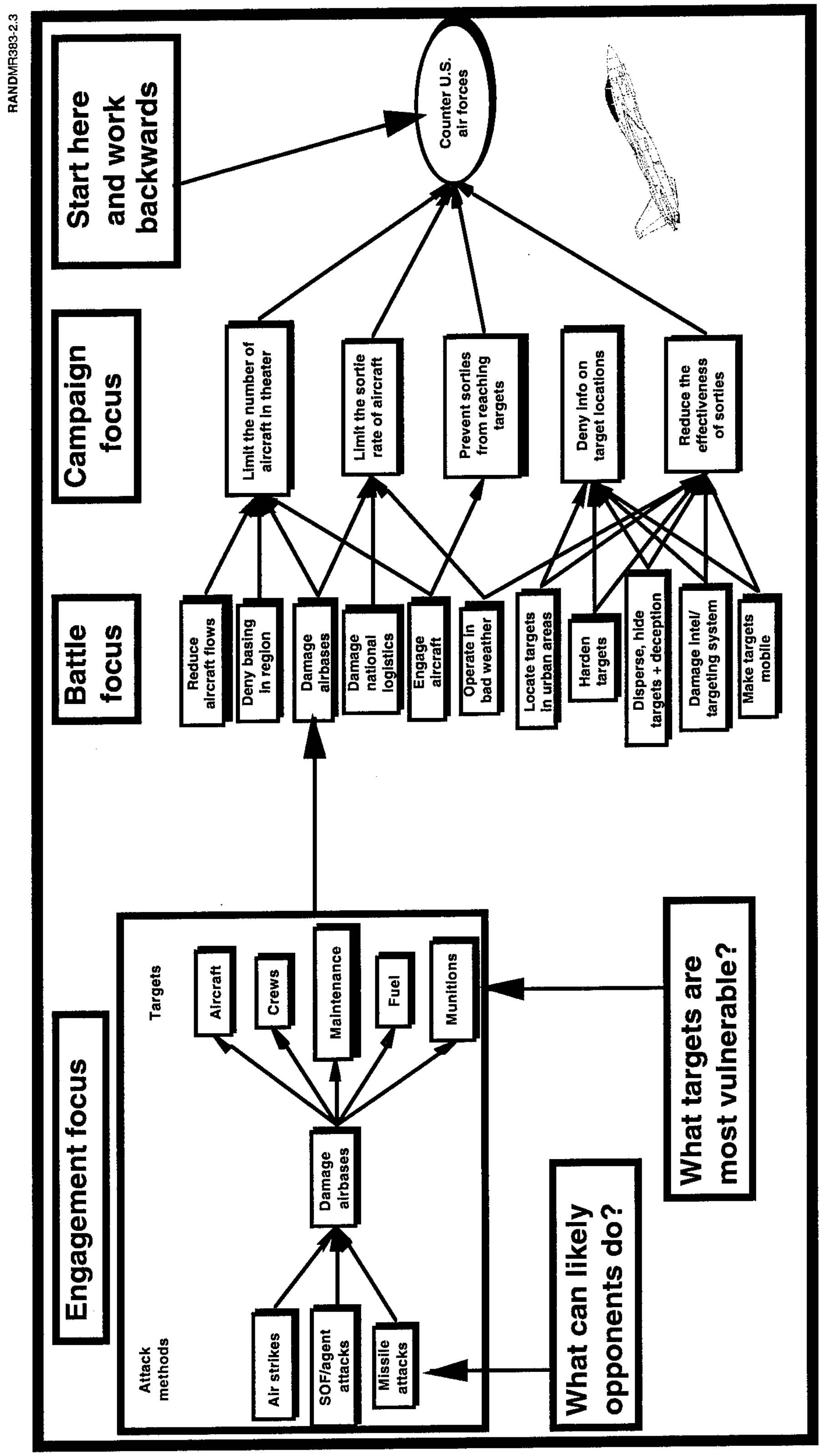

Figure 2.3—What Does a Threat Space Look Like?

could be made on the airfields, and such attacks could target some combination of the assets associated with airfields.

There is also a strategic element of the threat environment that involves characterizing procedures opponents may employ to deter U.S. intervention or otherwise shape the intervention to be less effective. Much analysis of major regional contingencies has treated a specific contingency as an isolated occurrence, allowing U.S. military power to be focused against a single adversary in a confined region. However, it should be obvious to prospective opponents that U.S. power can be diluted by involving it in multiple crises and conflicts around the world. Opponents would likely prefer to engage the United States when it is already involved elsewhere in the world, such as in Somalia or Bosnia,[12] and analysts should therefore pose contingency analysis in the context of ongoing, worldwide involvements rather than assuming that the United States can focus all its might against any given adversary.

The threat space and/or micro-world approach has the advantage of providing a top-down framework from which to do threat assessments. In it, analysts first determine what capabilities of prospective opponents may threaten the United States and its military forces. Analysts might conclude, for example, that an opponent having two nuclear weapons presented a different threat from an opponent having a dozen or more. We would then attempt to assess whether specific opponents could gain capabilities (and not just hardware) in one or more of these categories (analysts might conclude, for example, that while advanced aircraft like the Flanker might pose a real threat against U.S. air forces, few prospective U.S. opponents will likely be able to adequately absorb and employ such technology, and thus Flankers are not a substantial threat). These assessments would help identify the United States' requirements for intelligence analysis, suggesting specific opposition capabilities that should be searched for. They would also allow analysts to consider how the United States might respond to such opposition capabilities, and how the opposition capabilities are likely to change the character of conflicts with which the United States may become involved.

[12] U.S. opponents may even do what they can to stimulate conflicts elsewhere in the world (perhaps by supporting arms flows, and perhaps with other, more-direct involvement).

Warfare Environment Makes a Difference

Most models used in assessing major regional contingencies were originally developed to analyze combat on the Central European front. Moreover, analysts were trained in the force structures, doctrine, and other characteristics of Central Europe, and have tended to use these assumptions and models as the basis for all combat analysis. However, future major regional contingencies will likely occur under very different conditions, which we refer to as *warfare environments*. Warfare environments reflect factors such as

- the objectives and constraints of each side (and implied measures of success)
- the methods to be used by forces (doctrine, operational art, tactics, etc.)
- the resources available to each side (force structures and postures, technology, etc.)
- performance factors for each side (qualitative factors)
- allied cooperation available to each side
- other factors, such as terrain, weather, and infrastructure.

A new class of strategic variables needs to be defined to cover the differences in warfare environment among theaters. These variables should not be thought of as inputs to a combat model but rather as characterizations of warfare environments that would help ensure that the analyst conducts work in the right context.

From a modeling perspective, theater combat models need to be modified to reflect the differences suggested by the strategic variables. Thus, if infantry and artillery will dominate ground operations in a theater (as opposed to the armor and/or mechanized dominance assumed in most analysis and models), then combat rules should limit the mobility of the ground forces, make artillery a more effective killer of opposing forces (especially in causing personnel attrition), and attempt to refine the implications of counterbattery fires given the tactical approach and expertise of each side.

The Deployment Window for U.S. Forces Frames Future MRCs

The U.S. strategic principle of decisive force and the capabilities for decisive use of force possessed by the United States imply that U.S. involvement in an MRC, if allowed to go to its natural completion, will almost certainly lead to the defeat of opposing forces. However, the delay required to deploy U.S. forces into theaters (lacking significant forward deployments) gives opponents a window of

opportunity. If opponents wait until after that window is closed, the lethality of U.S. forces will likely overwhelm their conventional military forces (unless the opponents can revert to insurgency operations), and the conflict will tend to be settled fairly quickly on terms favorable to the United States. But if they can discourage U.S. involvement during the deployment window (which will last at least weeks if not months[13]), and break the U.S. will to intervene (given limited U.S. objectives), they may be able to succeed. They can partially undermine U.S. will if they have clearly achieved their objectives and are firmly able to pursue conflict termination during the deployment window (thus arguing for short wars). Thus, if it is clear that the United States has a good chance of intervening, opponents appear likely to prefer wars of short duration, since such wars may be the only kind that they can win. We recognize that a number of researchers have concluded that U.S. opponents will pursue long wars with the United States, and we address that alternative below.

As opponents recognize the deployment window phenomenon, they will likely attack deploying U.S. forces for two reasons. First, attacks on deploying U.S. forces will slow U.S. deployments, and thus lengthen the window of time available to the opponents. Second, such attacks, especially those that cause significant attrition, may undermine U.S. will. These two patterns argue against U.S. opponents' allowing U.S. forces to deploy into a theater unopposed (as happened in Operation Desert Shield).

Recognizing the vulnerabilities of the deployment window, the Department of Defense is seeking to apply new weapon technologies (such as sensor-fuzed weapons and other "smart" munitions) to enable a small number of early-arriving forces to at least neutralize the opposition offensive. The success of such efforts depends critically on the outcome of the deployment battle (Can opposition attacks prevent U.S. forces from gaining and sustaining a foothold in the theater?), and on the ability of the new U.S. technologies to respond to the type of enemy threat posed and the enemy countermeasures to the U.S. technologies (such as creating a nonlinear battlefield).

Alternatively, if the United States is unlikely to apply decisive force, RAND analysts believe that most U.S. opponents will strive for long wars. They will prefer long wars, believing that the United States will not have the staying power for a long war;[14] they can afford to press the United States against the limit of

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[13] A deployment could last several months, especially in a theater assigned second or lower priority among concurrent conflicts, given the evolving U.S. win-hold-win strategy.

[14] Analysis of the Korean and Vietnam Wars has shown that U.S. public opinion eroded seriously and that cumulative casualties appeared to have the major role in that erosion. See Mark A. Lorell and Charles T. Kelley, Jr., *Casualties, Public Opinion, and Presidential Policy During the Vietnam*

U.S. staying power if the United States cannot or will not bring decisive force to bear against them. When might the United States not bring decisive force to bear? Some possibilities are as follows:

- When the interest of the United States is not strong, the United States may vacillate on intervention, and as a result decide to commit only a small or token force initially (much as was done in Vietnam).
- When attempting to play peacemaker, the United States will naturally prefer a graduated response and will not likely commit a decisive force. For example, although the United States committed a fairly large force in Somalia, it was far from decisive in character; the U.S. force was sufficient to facilitate the distribution of food (the U.S. objective), but not sufficient to take control of the situation and overwhelm adversaries. Note that it is likely that many peacekeeping efforts will not be major regional contingencies, and thus will fall below the scope we are focusing on here.
- Historically, the United States has established limits on the commitment of U.S. forces that have prevented it from bringing decisive force to bear. For example, in the Vietnam War, operations across the Cambodian border were prohibited for a long period of time.
- Some opponents may be able to protect themselves from U.S. forces, using a variety of active and passive defenses.
- Some opponents may be able to protect themselves by pursuing insurgent operations, against which it is extremely difficult to bring decisive force to bear. Such cases will not often be major regional contingencies.
- When an opponent who desired a short war loses the strategic and operational initiative (as happened in the Persian Gulf War after several months of U.S. buildup), then the opponent must somehow shift to a long-war perspective to win, because it will likely lose a short war (and, in fact, will likely lose in any case).

The difficulty for the United States in winning a long war appears to be one of the major reasons behind the strategic principle of decisive force. However, as this list suggests, there are a number of plausible cases in which the United States may well find itself involved in a long war. We will not pursue these cases further here; instead, we turn to the cases for which we expect short wars.

War, RAND, R-3060-AF, November 1984, especially pp. 16–30. We anticipate a similar pattern in future long wars.

In the context of short wars, we expect that opponents will likely pursue limited objectives that can be achieved within one to four weeks, the time determined in large part by how long it will take the United States to make a major deployment into the theater. Thus, North Korea may be willing to settle for enveloping Seoul (although their policy still apparently contemplates capturing Pusan in two to three weeks). Or Iran might consider a move that controls the Persian Gulf rather than trying to capture and control all of Saudi Arabia and Kuwait. The opponent's strategic concept would be to secure its objectives before the United States could meaningfully intervene, then push for terminating the conflict on the basis of territory its forces have captured (which Iraq was unsuccessful in doing in the Persian Gulf War). Such a concept may imply opponents pursuing a sequence of conflicts in which marginal returns are achieved in each case, and the United States does not feel an overwhelming threat until its position in the region is thoroughly undermined (along the lines of Hitler's actions in the 1930s).

To minimize U.S. response and maximize the time available to both achieve its regional objectives and dissuade the United States from complete involvement, the opponent is likely to pursue maximum surprise and give the United States minimal response time. For example, in the Persian Gulf War, the United States' military response did not occur until after Kuwait had been captured. Historically, much of the military analysis community has argued against considering such short warning and/or response times because of (1) the need for opponents to mobilize and prepare to have maximum military capability in a conflict, and (2) the quality of U.S. intelligence and warning capabilities to perceive such preparations. The Persian Gulf War suggests that the United States needs not only the ability to perceive military preparations but also a more general understanding of what will happen (the problem faced by both the United States in the Persian Gulf War and the Soviet Union in 1940) and the will to respond given the various uncertainties in opposition intentions. One may also argue that, with limited objectives, an opponent may be willing to forgo some preparations (and thus give at best ambiguous warning) if by so doing the U.S. response will be delayed.

If the United States does choose to respond, opponents will likely attempt to precipitate strategic events that will cause the United States to reconsider its response.[15] Such events might well involve attacks that cause significant U.S. attrition. Opponents cannot be certain of how the United States will react in such cases; although likely U.S. responses can be correlated with some specific factors,

[15]A *strategic event* is an event that forces an opponent to rethink its objectives and/or strategy, likely leading to a subsequent change in activity.

U.S. responses are still highly uncertain and could involve either strengthening or weakening U.S. will.

As we examine the Persian Gulf War, it seems obvious that a major Iraqi mistake was to cede the strategic and operational initiative to the United States once Kuwait had been captured. We believe that prospective adversaries have learned this lesson and will attempt to retain the initiative. Having the initiative implies that they will pursue combat with forces and on terms most favorable to them, and also that they are unlikely to offer the United States an operational pause in which to deploy. Rather, even once they have achieved their objectives, they will likely oppose any attempted deployment by the United States, including preemptively acting to make deployments more difficult (e.g., closing straits, damaging airfields and ports, and mining harbors).

The defense analysis of FY92 focused significant attention on "simultaneous major regional contingencies"; in reality, the assumption was usually that the second contingency would develop well after the first. Defense budget pressures are now pushing the United States away from even such a sequential MRC requirement and more toward an ability to handle only a single major regional contingency at a time. Such capability limitations raise an important opportunity for prospective opponents; we see opponents as having every incentive for executing simultaneous attacks. Some have argued that truly simultaneous attacks would require prior coordination, and that prospective U.S. opponents are unlikely to be able to orchestrate such cooperation. However, prospective U.S. opponents are being increasingly isolated from the rest of the world and share many interests; for example, several such states have shared ballistic missiles and ballistic missile technology, and they may be sharing nuclear technology.[16] It is not clear that such joint efforts will lead to true alliances, but they could well lead to limited coordination of efforts, given the mutual benefits that could accrue from diluting the U.S. response.

Short wars have several implications for analysis and modeling. In particular, we should focus on contingency cases that involve short warnings. These cases should include initial U.S. deployments only a day or two before the opposition attack, as well as initial U.S. deployments after the opposition attack. In contrast,

[16]"Western intelligence sources report . . . a series of secret deals between the Stalinists of North Korea and the ayatollahs of Iran. Under the arrangement, Tehran is giving the Pyongyang government $500 million to help it develop a ballistic missile system that could deliver nuclear and chemical warheads to targets in Japan. In return, North Korea has agreed to sell an unspecified number of nuclear bombs to the Iranians and to provide them with designs for nuclear-weapons-reprocessing plants. According to one estimate, by 1995 the North Koreans could possess sufficient weapons-grade plutonium to manufacture as many as seven bombs." "Washington Whispers," *U.S. News and World Report*, March 29, 1993, p. 18.

historical scenarios used for major regional contingencies have tended to assume that the United States began its deployments into the theater some 10 to 20 days before the enemy attack. Such long-warning cases should not be ignored, because they may be possible; they will likely constitute cases of U.S. operational dominance and thus be relatively easy to evaluate.[17]

In addition, analysts need to consider cases involving truly concurrent contingencies. Such a focus is current U.S. policy, a decided departure from the approach in previous administrations. Analysis of concurrent contingencies is not as simple as dividing all U.S. forces between two theaters and immediately deploying those forces. Instead, analysts must be prepared to assess the fraction of the force structure that can actually be deployed with any given level of warning, and the requirements for logistics support and maintenance, which may limit the forces that can simultaneously operate in two or more locations around the world.[18]

To properly define likely micro-worlds for the future, analysts need to better understand the limited objectives that opposing nations may seek to obtain through warfare, as well as the strategies they might employ to achieve broader goals through a series of limited attacks. Analysts must pursue these objectives in theory first to define meaningful options, then to develop potential military strategies and operations that might correspond to such objectives.

The strategic events mentioned above become the key discontinuities of future warfare that may invalidate the standard analytic assumptions of continuity in warfare. Analysts therefore need to better understand what might constitute such strategic events, and to identify patterns of conflict that may develop with or without such events.

Analysts need to be able to analyze a much wider set of cases with theater-level models, to include many courses of events and phenomena not usually handled in previous theater-level models. In particular, analysts must address opposed deployment operations and the implications such operations will have for the flow of logistics and the damage that might be done to U.S. forces and support.

[17]Even these longer-warning cases still require the mobilization of combat support and combat service support, which can take longer than the warning assumptions may allow. It is critical to consider the time required for total force employment, not just the deployment of combat forces.

[18]For example, if in peacetime U.S. forces are involved in peacemaking in several countries, and the United States is then challenged to respond to two simultaneous MRCs, to what extent would the peacemaking operations have to be abandoned, and in what other ways would compromises have to be made on logistics? For example, during Operation Desert Storm, almost no C-141s supported operations in Korea, and significant quantities of advanced ammunition supplies were moved from Korea to the Persian Gulf to sustain operations. This information poses some serious questions about what would happen in a simultaneous conflict in Korea and the Persian Gulf.

Historically, theater-level models have not tended to be strong in assessing logistics requirements and implications. Where such issues were captured, they tended to relate to long-term force sustainability. The focus on short wars and opposed deployments suggests that, in the future, we may have more need for evaluating logistics in terms of short-term force viability. That is, Can the United States deploy forces into a hostile environment so that they will have the various components required to operate and defend themselves from the beginning? The United States Marine Corps has always developed its forces into such packages, making short-term sustainability and support an integral component of the deployed force. Such packaging may be required for other forces, as well, and we will need to evaluate the requirements of proper packaging, as well as the implications of inadequate force packaging on short-term operations.

Asymmetrical Battles Will Likely Dominate Future Warfare

Another pattern we have observed in our gaming and analysis of future warfare is that battles may well become asymmetrical[19] because many U.S. military strengths rest on more than just technology. They also rest on cultural elements, such as training approaches and the susceptibility of personnel to training, the willingness and ability to delegate authority and support independent operations by subordinates, and so forth. For example, as shown in the Persian Gulf War, even if U.S. opponents acquired Flanker or Fulcrum aircraft, they would not likely pose a major air threat against U.S. air forces (although such beyond-visual-range weapons as the advanced medium-range air-to-air missile [AMRAAM] may change this relationship).

However, there are other ways to counter U.S. strengths. The threat space framework illustrated in Figure 2.3 has helped us recognize that opponents can often find a wide range of counters, many of which do not require the skill, training, or other U.S.–unique attributes behind U.S. strengths, and therefore are within the reach of prospective U.S. opponents. Because these counters are not symmetrical with U.S. capabilities, U.S. analysts have tended to discount them in their analyses (after all, the United States has chosen not to pursue many of these approaches, so how important could they be?), despite the fact that the capabilities such counters target (such as U.S. intelligence dominance) are often

[19] *Asymmetry* means fighting with means (forces) and in ways (operations) different from those of the opponent. An opponent would not attempt air-to-air combat it could not win against the United States; rather, it would attack U.S. airfields with missiles and special operations forces to destroy U.S. fighters and the ability to generate sorties.

highly concentrated target systems that are relatively fragile and susceptible to damage.[20]

The focus of prospective opponents on other approaches to military engagements will likely lead to a new kind of long-term military competition. Rather than the historical pattern of competition in largely symmetrical areas, analysts should expect opponents to pursue various technologies in a combined-arms approach to deal with U.S. strengths. In their efforts, prospective opponents will likely find that some military technologies have high value for them, and some of these technologies will be ones the United States developed but then abandoned because they did not fit its combined-arms approach. For example, prospective opponents may find particular value in a FOG-M (a fiber-optic–guided anti-armor munition with a range of perhaps a dozen kilometers or more, which is also effective against helicopters and aircraft), and they would likely pursue a capability to mount sensor-fuzed weapons on cruise missiles for delivery against U.S. armored forces.

In examining these possibilities, it is important to note that we expect future opponents to attempt to maintain the initiative in war. To the extent that they are successful, they will determine the basic character of the engagements waged in future wars and will undoubtedly exploit their strengths. If future opponents have military strengths different from the United States, analysts should expect asymmetrical battles.

That future battles will be largely asymmetrical has implications for major regional contingency analysis and modeling. It implies that analysts must be prepared to deal with a much broader variety of engagements than they have historically dealt with, to include theater strategic attacks, rear-area battles, and so forth. It is not clear that analysts need to be able to model all such engagements (although building models of such engagements would often be preferred), but they must be able to include the effects of such engagements in an overall theater assessment, and balance those effects against the more traditional types of battles for which models do exist. For example, a recent war game included a special forces/ballistic missile attack (using chemical and advanced conventional munitions) on the main oil terminal and storage facility in a defending country. It may be unreasonable to expect models in the future to adequately represent such attacks, but the analyst needs to be able to assess them and include the effects (in this case, a severe shortage of POL, which would

[20]This point has been made repeatedly in the JICM Working Group by an intelligence community representative, who has noted that the key elements of command and control in Operation Desert Storm were concentrated in the "Black Hole" in Riyadh and in a few other places that could have been susbtantially damaged by quite limited attacks.

reduce aircraft and helicopter sorties, limit the mobility of heavy forces, and restrict resupply operations) in the overall theater assessment.

Analysts must also develop a much more thorough understanding of the potential vulnerabilities of forces and target systems to a wide variety of attacks. In many cases, the analyst must be prepared to suggest how emergent capabilities may be employed, since it is unlikely that a doctrine will have been developed for such capabilities. Analysts should also expect that opponents will tend to employ combined-arms threats, and thus each attack must be viewed in combination with other actions being taken to the same or similar ends, and not just in isolation.

To the extent that asymmetrical engagements dominate future warfare, most existing models of major regional contingencies will not accurately reflect the key engagements and battles that will develop because existing models usually employ symmetrical doctrine, tactics, and other characteristics of the forces on both sides (and between theaters). Because our war gaming and analysis have compared traditional battle assumptions with assumptions that appear closer to how forces will actually fight in the future, we have realized that many of today's model outcomes can be wrong.

Theater-level models will have great difficulty in dealing with nonlinear battlefields; nevertheless, they must be able to do so. We see every evidence that the lethality of forces on both sides, as well as the stochastic nature of local breakthroughs and the evolving force doctrines, will favor nonlinearity. For example, the North Korean doctrine on exploiting breakthroughs is different from the historical Soviet doctrine,[21] and appears more likely to lead to a very nonlinear environment (which, not surprisingly, would make the employment of U.S. air power more difficult).

Nuclear Weapons Owned by Regional Powers May Overshadow Contingencies

In recent years, considerable emphasis has been placed on countering nuclear weapon proliferation. Despite such efforts, it is clear that several countries beyond the five recognized nuclear powers have attained or are pursuing a

[21]Historical Soviet doctrine on breakthroughs envisioned the penetrating forces turning after penetration of NATO formations and rolling up the flanks of the penetration to provide an operational-size corridor for penetration into the NATO rear, while sending other forces deep into the NATO rear. In contrast, North Korean doctrine emphasizes deep penetration in the aftermath of a breakthrough without such widening efforts, apparently assuming that many of the defending forces will lose cohesion and collapse once penetrated, and that the nonlinearities of the resulting battlefield make air interdiction a much more difficult proposition.

nuclear capability. As we consider future major regional contingencies, in many cases one or more of the regional parties will either clearly have nuclear weapons or may have nuclear weapons (and the United States may not know for sure).

Our gaming and analysis have identified three principal reasons for regional powers having interest in nuclear weapons. First and foremost, many countries perceive a need to acquire nuclear weapons in the context of regional conflicts in which they are or may become involved. Thus, conflicts between India and China were a major reason for India's developing nuclear weapons in response to China's possession of nuclear weapons; in turn, India's development motivated Pakistan to pursue nuclear weapons to maintain a regional balance of power. Second, nuclear weapons are viewed by many regional powers as the ultimate means for ensuring regime survival (the survival of their society, or at least the key elements of the society as perceived by the regime leadership), giving the regime a weapon that will help deter attacks against it, or that will counter those attacks should they occur. This objective is often correlated with the first objective and becomes the key end to which at least the first few weapons acquired would probably be devoted. Third, once sufficient nuclear weapons are acquired they may be viewed as a vehicle for causing strategic events in regional conflicts; this objective may extend to challenging U.S. will and operational dominance in conflicts where the United States decides to intervene.

Other weapons of mass destruction may offer similar, although perhaps not as great, leverage for regional powers. The attitude displayed toward chemical weapons in Operation Desert Storm showed how serious a role such weapons can play in future warfare; moreover, in an era when casualty minimization appears critical to public support of regional contingencies, a single use of chemical, biological, or nuclear weapons could easily test the willingness of the United States to be involved in such a conflict. Because nuclear weapons pose the greatest threat and have become the focal point of recent counterproliferation efforts, we focus on them for the remainder of this section, recognizing that many of the observations made here would apply equally to other weapons of mass destruction.

Whereas various delivery means may be employed with nuclear weapons, most countries working on nuclear weapons seem to have chosen ballistic missiles. However, we also see some evidence of interest in cruise missile technology in these countries and suspect that cruise missiles may become an alternative

delivery means during the next decade.[22] The choices here are important: Much effort has gone into controlling ballistic missile proliferation because of its clear tie to nuclear weapons; much less emphasis has been placed on countering cruise missile proliferation. Operationally, cruise missiles simplify the delivery of chemical or biological agents and of some improved conventional munitions, such as fuel air explosives, because cruise missiles make it much easier to dispense these munitions in appropriate patterns around targets.

If a prospective opponent in a major regional contingency may possess nuclear weapons, we believe that U.S. willingness to intervene and procedures for intervening may change substantially. For example, given the likely interest of opponents in neutralizing early U.S. deployments, the United States may not be able to deploy in ways that create local, high densities of U.S. military forces (e.g., at a port or airfield) for fear that such concentrations would offer too attractive a target.

If a prospective opponent threatens nuclear strikes against one or more regional allies on whose territory the United States will need to stage or base forces, the United States may be denied the facilities and host-nation support needed to project power. For example, if a nuclear-armed Iraq were to threaten an attack on Riyadh should the Saudi government allow U.S. entry into that region, the United States may not be able to depend upon positive (or at least immediate) Saudi support.

Strategic attack with conventional munitions has become a key tenet of U.S. air doctrine. One component of strategic attack is to threaten the opposing regime and its ability to control its military forces. If the opposition has acquired nuclear weapons explicitly to deter such attacks and to retaliate should they occur, must the United States reconsider its air doctrine?

U.S. use of nuclear weapons either preemptively or in retaliation may also have strategic implications. The United States has become increasingly reliant on coalitions, as much to politically justify involvement in regional conflicts as to muster sufficient military power for victory. But some participants in any given coalition may be unwilling to have the United States use nuclear weapons, and may be prepared to abandon the coalition should the United States decide to proceed on its own; the United States could thus find itself deterred from nuclear weapon use by some of its allies.

[22]"A classified Pentagon study said Syria, Iran and China are aggressively developing cruise missiles—the first ones are expected operational by the year 2000." "News Highlights," DoD's *Current News: Early Bird*, February 1, 1993, p. 16.

In the major regional contingencies considered in Figure 2.2, there are few cases where the United States will be absolutely certain that prospective opponents do not have nuclear weapons. Therefore, analysts need to consider most threat spaces as being affected by a "nuclear shadow," and apply this shadow to the specific micro-worlds examined. Analysts need to pay specific attention to regional powers' actual or threatened use of nuclear weapons against early U.S. deployments (in order to destroy U.S. will), or against U.S. counteroffensive operations (which will tend to threaten opposition regime survival). Analysts also need to better understand the implications of opposition nuclear weapons on U.S. theater and/or strategic attack doctrine (which will also threaten regime survival), as suggested above.

Although some analysts have considered that strategic offense and/or defense models should be adopted to analyze theater nuclear weapon use, we believe that such models oversimplify the problem and ignore key combat interactions. For most prospective opponents, it will be easier to defeat a Patriot defense by having special operations forces (SOF) fire a rocket-propelled grenade (RPG)-7 into the Patriot radar than to attempt to leak missiles through the Patriot defenses. And it is more likely that the United States will try to suppress opposing missiles by air strikes and similar efforts than to assume that missile defenses are the only response to opposition nuclear weapons.

There is no requirement that the United States cede the initiative in war, especially at the operational level, to prospective opponents who possess nuclear weapons. However, if the United States wants to preempt the opponents' nuclear attacks or retaliate positively, it must first define the appropriate targets and means of attack. This definition must be done on a country-specific basis, and in considerable detail, because analysts can expect that nuclear weapons infrastructures will be limited, hidden, and otherwise protected, and analysts will not be likely to understand how opposition nuclear infrastructures work unless the United States applies significant collection and analysis resources to such an effort (and even then the United States may not succeed).[23] We must also be able to estimate how well the United States understands the opposition's nuclear infrastructure, and how confident it might be in destroying that infrastructure. In the Cuban missile crisis in 1962, one of the options formulated for a response to nuclear missiles in Cuba was a so-called surgical strike to preemptively destroy the missiles. When asked about the likely effectiveness of the strike, "the Commander of the Tactical Air Command replied that the air

[23]While there are many things that U.S. intelligence platforms may determine, in the end it is likely that some form of human intelligence will be required for the collection and analysis tasks of the definition process, and this intelligence may be very difficult to obtain.

strike would certainly destroy 90 percent of the missiles but that it was not possible to guarantee 100 percent effectiveness. According to Sorensen's record, 'Even then,' admitted the Air Force—and this in particular influenced the President—'there could be no assurance that all the missiles would have been removed or that some of them would not fire first.' Few assertions could have made the air strike less attractive to the leaders of the U.S. government."[24] If uncertainty in such estimates will be key to national decisionmaking, analysts must be prepared to make estimates of that uncertainty.

Analysts face a somewhat different problem in attempting to analyze retaliations against the use of nuclear weapons. In war games, we have observed that players have great difficulty trying to define an appropriate set of targets for a nuclear response. In the definition process, they face two problems. First, ideally, they would like to be able to respond against the opposition nuclear weapons, but they usually lack sufficient intelligence to do so. Second, it is difficult for the modeler to prepare appropriate target information for a nuclear retaliation: By the time nuclear weapons are used, the U.S. conventional strategic campaign has destroyed many of the targets that would be appropriate for a nuclear response, leaving few viable targets for response and little operational military requirement for such a nuclear strike (in the words of many of the players, "We can achieve our damage objectives with conventional munitions, so why use nuclear weapons?"). The implications of the U.S. response to enemy employment of nuclear weapons is further complicated by second-order consequences. If the United States concludes that everything that can be done is already being accomplished through conventional attacks, then the enemy (or other potential enemies) may conclude that there is little downside risk to employing nuclear weapons against U.S. forces.

In assessing the implications of third-party nuclear use, analysts need to better model the implications of nuclear detonations on early deployments of ground, air, and naval forces, including not only the losses to nuclear weapons but also the effect of a nuclear strike on the viability and support of the military force. Analysts must also understand the effect of nuclear detonations on force cohesion: In war games, even a small nuclear strike that caused only modest attrition (i.e., a few hundred people) has tended to blunt the momentum of almost all counteroffensives, a likely target of opposition nuclear weapons.

Analysts must also be prepared to evaluate the effect of fallout from nuclear detonations. For example, a U.S. nuclear response against North Korean nuclear

[24]Graham T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, Brown, and Company), 1971, p. 126.

weapon use would most likely cause fallout that would drift over Japan; analysts need to be able to evaluate the relative magnitude of such fallout, since even very small amounts may cause major political reactions (as have the dosages that have caused a furor in southern Utah as a result of atmospheric testing in the 1950s).

3. Geographic Modeling

Arthur Bullock and Carl Jones

During its ten years of development, RSAS representation of world geography changed little from the original design, which called for regions, such as "France" or "US-SouthEast" to serve as the basic accounting locations for land, air, and sea forces and for facilities, with little further resolution of geographic location. As the two models of theater warfare, CAMPAIGN-MT and CAMPAIGN-ALT, were incorporated in the RSAS, their needs were accommodated by extending the concept of "region" to also include various types of "overlay regions."[1] In the Main Theater (CAMPAIGN-MT) model (which covered Central European and Korea), a modified piston and/or axis overlay required the RSAS user to become familiar with four additional levels of geography: zones, axes, sub-theaters, and theaters, with a series of complex rules regarding what was meant if ground forces were deployed to one of these types of locations. The Alternate Theater (CAMPAIGN-ALT) model used an entirely different concept of theater, line-of-communication (LOC)-axis, and point-axis to represent a pseudo-network model for use in all other areas where land and/or air combat was of analytic interest. Finally, the sea regions of the world were overlaid with several different types of higher-resolution areas: subordinate sea-areas, choke-points, and patrol boxes. The relationships among these maritime geographic entities were even more complex than the land geography and were understood by few. The complexity and unnaturalness of these representations have become a source of irritation for RSAS users and developers alike.

The requirement to integrate the CAMPAIGN-MT and CAMPAIGN-ALT models into ITM provided the opportunity for (and perhaps even necessitated) a review of RSAS geography. It was decided at that time to revise the geographic representation coincident with the implementation of ITM, according to the following principles:

- Simplify the process of creating or modifying geographic data and provide the capability to create or modify geography dynamically (during model execution).

[1]The overlays used in the RSAS are described in Bruce W. Bennett et al., *Main Theater Warfare Modeling in the RAND Strategy Assesment System (3.0)*, RAND, N-2743-NA, September 1988, pp. 8–11.

- To the extent possible, eliminate duplication of geographic data sources among the JICM-C and JICM-A models and the graphics models.
- Global geography should be modeled independently of ITM but at sufficient resolution to provide the land network structure needed by ITM. This one land network is thus the basis for ITM, as well as for all other JICM global modeling of land positioning and mobility.

This section summarizes the new JICM geographic modeling and describes the progress of conversion as of the JICM 1.0 release. Terms that have specific meaning within this implementation (as opposed to having broader meaning) are shown in **bold** in this section.

Geographic Entities (Objects)

Regions

All JICM **regions** now represent natural geographic areas. The **region** is the grossest level of geographic resolution. All JICM **regions** are defined in data file geog.sec. They include information such as the **region** owner (the government that controls the **region**), the location of the geographic centroid of the **region**, the values of many parameters affecting forces in the **region**, and much more. There is also a binary data file (latlon.unc), which sets up a one-to-one correspondence between every integer latitude-longitude pair and a JICM **region**.[2] This data file is used as a basis for automatically editing data files for geographic correctness, and for determining the current **region** of simulation entities whose position is changing rapidly (e.g., an ICBM or aircraft in flight). There are two types of JICM **regions**: land and sea.

Land Regions: Each of these **regions** generally represents an individual country, except where more than one is needed because of noncontiguity (e.g., Alaska and Hawaii are separate **regions**) or overly large size (e.g., CONUS is broken up into six **regions**). Data for the South American and African continents have been much expanded, and, with the breakup of the former Soviet Union, Yugoslavia, and Czechoslovakia, the list of land **regions** for Europe and Asia has been reworked.[3] Table 3.1 lists all JICM 1.0 land **regions**.

[2]There is currently no direct connection between JICM **region** data and the graphics programs that display JICM **region** boundaries, so data and boundries must be kept consistent by manual coordination only.

[3]For example, the regions USSR-West, USSR-SouthWest, and USSR-Central-Asia have been eliminated in favor of the various new republics. The former USSR regions now part of Russia have been renamed: Russia-FarEast, Russia-Moscow, Russia-NW (formerly USSR-Leningrad), Kaliningrad, Kamchatka, KurilIslands, NorthCaucasus, Siberia, and Urals.

Table 3.1

JICM 1.0 Land Regions[a]

US-NCentral	Austria	Algeria	Afghanistan	Argentina
US-NEast	Albania	Angola	Bahrain	Belize
US-NPlains	Azores	Benin	Iran	Bolivia
US-SCentral	Belgium	Botswana	Iraq	Brazil
US-SEast	Bulgaria	Burkina	Israel	Canada-East
US-West	Cyprus	Burundi	Kuwait	Canada-West
	CzechRepublic	Cameroun	Lebanon	Chile
Alaska	Denmark	CAfricaRep	Oman	Colombia
Aleutians	Finland	Chad	Pakistan	CostaRica
Hawaii	France	Congo	Qatar	Cuba
Guam	FRG-East	Djibouti	SaudiArabia	DominicanRep
PuertoRico	FRG-West	Egypt	Syria	Ecuador
	Greece	Ethiopia	Turkey-East	ElSalvador
	Greenland	Gabon	Turkey-West	FrenchGuiana
Kaliningrad	Hungary	Ghana	Yemen	Guatemala
Kamchatka	Iceland	Guinea	UAE	Guyana
KurilIslands	Ireland	IvoryCoast		Haiti
NorthCaucasus	Italy	Kenya		Honduras
Russia-FarEast	Luxembourg	Liberia	Bangladesh	Mexico
Russia-Moscow	Netherland	Libya	Burma	Nicaragua
Russia-NW	Norway-N	Mali	Cambodia	Panama
Siberia	Norway-S	Malawi	India	Paraguay
Urals	Poland	Mauritania	Indonesia	Peru
	Portugal	Morocco	Japan	Surinam
Armenia	Romania	Mozambique	Jordan	Uruguay
Azerbaijan	Slovakia	Namibia	Okinawa	Venezuela
Belarus	Spain	Niger	Laos	
Georgia	Sweden-N	Nigeria	Malaysia	
Estonia	Sweden-S	Rwanda	EastMalayia	
Kazakhstan	Switzerl	Senegal	HongKong	Antarctica
Kirgizia	UK	SierraLeone	Mongolia	Australia
Latvia	Zealand	Somalia	NorthKorea	NewZealand
Lithuania		SouthAfrica	PRC-NE	Philippines
Moldova	Bosnia	Sudan	PRC-SE	PapuaNewGuin
Tadzhikistan	Croatia	Tanzania	PRC-West	Madagascar
Turkmenistan	Kosovo	Tunisia	Singapore	
Ukraine	Macedonia	Uganda	SouthKorea	
Uzbekistan	Montenegro	WestSahara	SriLanka	
	Slovenia	Zaire	Taiwan	
	Serbia	Zambia	Thailand	
		Zimbabwe	Vietnam	

[a]In **regions** and **places**, there is no space between words in a multiple-word name.

There are no longer any land overlay regions. What used to be theater concepts (of both command and geography), such as CEur and WTVD, are now represented only as **command** entities, not as geography. Instead of defining pseudo-geography and assigning forces to operate there, **commands** are given control of forces and are also given an area of operation in terms of real geography. Use of **commands** in ITM simulations is discussed in Sections 4 and 5.

Sea Regions: These represent all the world's maritime areas. For convenience of modeling and accounting, some of the larger oceans and seas are represented by multiple sea **regions** (e.g., the Pacific is represented by six JICM **regions**). Also, the naming of these **regions** is sometimes influenced more by modeling convenience than by textbook geography (e.g., GI-Gap is included because of common usage in lieu of Denmark Strait, its true name).[4] There are no longer any separate representations of subordinate sea-areas. Choke-points are no longer a separate class of entity but are simply subsets of the sea **regions**. Table 3.2 lists all JICM 1.0 sea **regions**.

The difference between normal sea **regions** and choke-point sea **regions** relates to the modeling of transit through these **regions**. Normal sea **regions** are assumed convex, i.e., a ship can move along the great circle between any pair of points in them. In choke-point **regions**, this assumption is relaxed, because they have a specific entry point on each end and a centroid position through which all transits pass.

The only major geographic features not currently explicitly represented by a named **region** in JICM are the Great Lakes and the Caspian Sea (represented still as parts of the land regions that abut them). These could be added if ever required.

Land Networks

Each land **region** also has been provided with a surface movement network whose basic structure is provided in a new JICM data file, place.unc. The contents of this file define data for two new geographic concepts: **places** and **links**. Whereas **region** is an area concept, a **place** is a point concept and serves as a node in the surface network. **Links** define direct surface (road or rail)

[4]The list of sea **regions** in JICM 1.0 was developed in cooperation with the U.S. Naval War College and was specifically chosen to give broad areas in which the least-detailed antisubmarine warfare modeling could be reasonably represented for war gaming purposes. Finer naval geographic resolution is provided by seaboxes (formerly called patrol boxes), as described below.

Table 3.2

JICM 1.0 Sea Regions

CanaryBasin	ENEPacific	AdriaticSea
EastAtlanic	ESEPacific	AegeanSea
EquatAtlantic	NCPacific	AlbBasin
IberianLant	NEPacific	BlackSea
MidAtlantic	NWPacBasin	EastMed
SouthAtlantic	NWPacific	MidMed
WestAtlantic	SEPacific	SicilianStrait
WestEurBasin	SWPacific	SuezCanal
		TurkishStrait
BarrierBarents	KurilStrait	TyrhennianSea
EastBarents	NEKurilWedge	WestMed
KaraSea	NEOkhotskSea	
MurmanskCoast	NWOkhotskSea	
WestBarents	OkhotskSea	
ENorwegianSea		AdenGulf
NENorwegianSea	AleutianHaven	ArabianSea
NNorwegianCoast	BeringSea	BabMandb
NWNorwegianSea	CelebesSea	EastIndian
SNorwegianCoast	EastChinaSea	HormuzStrait
WNorwegianSea	FormosaStrait	MalaccaStrait
	HookHokkaido	MoluccaStrait
BalticSea	JapanSea	NArabianSea
CanalZone	JavaBandaSeas	OmanGulf
Caribbean	KoreaStrait	PersianGulf
EnglishChannel	LaPerousStrait	RedSea
FloridaStrait	LuzonStrait	SundaStrait
GIGap	MakassarStrait	WestIndian
GibraltarStrait	PTGBay	
GulfMexico	PetroBay	
HopePassage	PhilippineSea	
HornPassage	SakhalinStrait	
HudsonBay	ShikoBasin	
IUKGap	SouthChinaSea	ArcticAtlantic
LabradorSea	TatarStrait	ArcticPacific
NorthSea	TorresStrait	NorthPole
SkagerrakStrait	TsugaruStrait	
SvalbardStrait	YellowSea	

connections between **places**; more specifically, they define the arcs of a network, and may pass through no intermediate nodes (**places**) and intersect no other arcs (**links**). Thus, arcs intersect only at nodes. The JICM input processor checks to ensure these assumptions are not violated.

Figure 3.1 shows what the land network looks like for the continental United States in JICM 1.0. For example, LasVegas (note that this name has no space in it) is a **place**, and the connection between LasVegas and SaltLakeCity is a **link**. It would not be permissible to have a direct **link** from LasVegas to ElPaso because it would pass over the **link** between Phoenix and Albuquerque. Instead, ground movements from LasVegas to ElPaso would normally pass through Phoenix. In these maps, **links** are always shown as straight lines between **places**. This does not mean that the **link** is exactly along that line, which in some cases may be drawn over water or other impassable features, but is rather drawn this way to require the minimal input from the user.

The **place** data are specified first in place.unc. Each **place** is provided with a unique interface name (which may include no blank characters), which is usually the name of a city or town (e.g., NewYork, Seoul, and Moscow are **places** in the current data base) but need not be (e.g., JctSKor1 is the name of a **place** needed to describe a major network node in South Korea that is not located anywhere near a town). Each **place** is also located to the nearest hundredth of a degree latitude and longitude, and, if appropriate, its usefulness as a seaport is also described (in terms of available berths and throughput). It is also possible to specify who is in

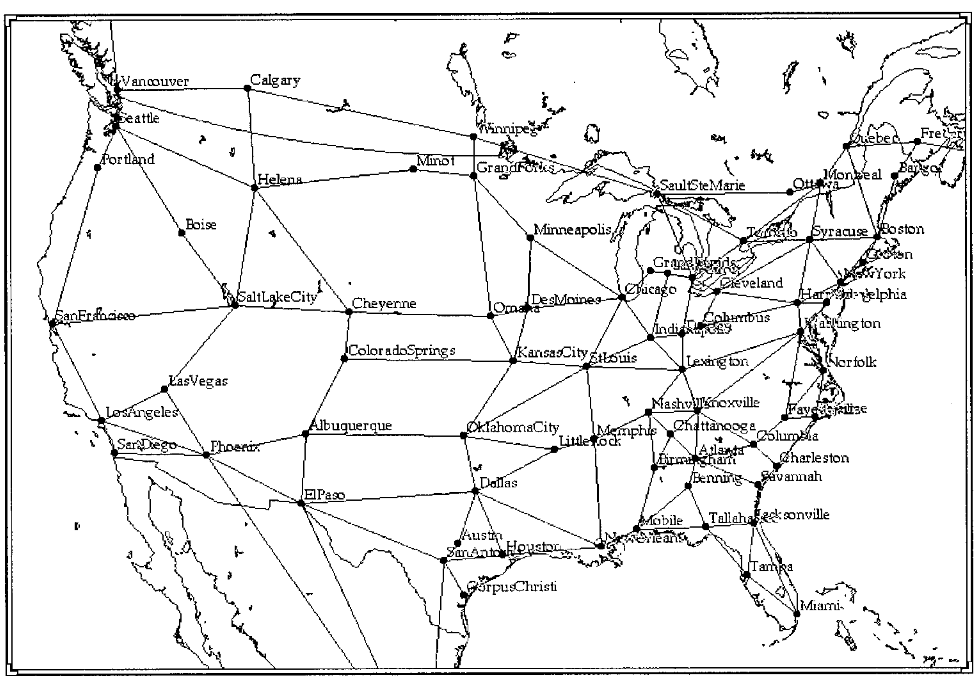

Figure 3.1—The JICM 1.0 Network for CONUS

control of a **place**. By default, this is the owner of the **region** in which the **place** is located but may be set otherwise. For example, the United States controls DiegoGarcia and Guantánamo, and Israel controls Jericho and Hermon in the JICM 1.0 **place** data.

Places may also be used to represent islands that are too small to justify defining a separate **region**. For example, DiegoGarcia and Bermuda are represented as "island" **places** of the land **region** UK, but they are located appropriately in sea **regions** WIndian and WAtlantic, respectively. The only limitation in treating them in this manner is that they cannot be connected to other places by a surface network. Islands large enough to justify a surface network of their own have been represented as separate land **regions**.

In the RSAS, seaports were not represented explicitly, and each **region** could only have one sea entry. These constraints made it necessary to split many land **regions** simply because they had ports on more than one sea (e.g., Australia and Saudi Arabia), and, in fact, many land **regions** that should have been split were not (e.g., US-South-East actually abuts the Atlantic and the Gulf of Mexico). Also, the coastline of many **regions** is quite long, making the assumption of one conceptual seaport difficult to justify. In JICM 1.0, a seaport is an attribute of a **place**, not of a **region**, eliminating this problem and allowing a number of previously split land regions to be consolidated again (e.g., Australia and Saudi Arabia). It is now even possible to move ships within a **region**, e.g., from Norfolk to Jacksonville. These named port places may also be used as target locations for air and missile strikes.

Link data are also quite simple to generate, requiring only the naming of the pairs of **places** to be connected. By default, the road distance between **places** connected by a **link** is assumed to be the great-circle distance times a parameter (1.10 by default), but explicit distances or distance multipliers can be provided, if necessary, to refine the data. Also, if a **link** crosses an international border, the border is assumed to be midway between the two **places** unless the data specify otherwise (e.g., the German-Polish border is explicitly defined to be 6 percent of the way along the **link** from FrankfurtOder to Poznan).

Whether calculated by default or provided directly in data, road distances are used to only the nearest tenth of a kilometer, and that is also the greatest accuracy allowed for border positions and positions of forces along a **link**. The syntax for specifying surface position is either exactly at a **place** (e.g., Seoul), or at a between-**place**-position, (e.g., Washington/52.8Kms/Richmond, meaning 52.8 kilometers away from Washington along the **link** to Richmond). If one wished to

locate a force exactly at a border, it is permitted to use "border" in lieu of stating a distance (e.g., Boston/border/Quebec).

Terrain Data

The network of **places** and **links** just described is sufficient for positioning and routing forces and can be used to specify where combat will be simulated, but it does not include enough geographic data for simulating combat. The **places** and **links** are one-dimensional (points and arcs only); combat forces have varying capabilities according to the type and expanse of battlefield terrain. In short, battles require area data. The geography design allows for any **link** to be overlaid by one or more **terrain** descriptors, which describe length, width, and type of **terrain** along the link. There are now six JICM **terrain** types: urban, mountain, rough, open, mixed, and river. Section 4 describes how to lay out an ITM theater, including how to prepare **terrain** data.

Land Routing

All JICM **ground forces** and mobile **missile forces** move across the network in response to deploy orders. The JICM user now has the capability to control force movement precisely by specifying a complete route for movement. If a path is being specified as a line of communication (LOC) along which a ground **command** is to operate, it must be a precise path (naming every **link** in order). To facilitate this requirement, we added a capability to define named land paths, described in Section 4. For example, one can name "Axis-3" to mean the precise path along the **links** between Osan, Suwon, Seoul, Uijongbu, etc. If a path is being specified for the deployment of a force, it need not be precise but requires only that the final destination be stated. This assumes that the user will be content with the model's rules for choosing strategic airlift or sealift as needed and for selecting a specific path.

The syntax for specifying a LOC or a deployment route is an ordered set of **place** names separated by ">" symbols and ending with the destination position. For example, the path Fayetteville>Columbia>Charleston>Savannah>Savannah/20Kms/Jacksonville means to transit from the origin (wherever the force is now) to each **place** named in the order stated, stopping on the **link** from Savannah to Jacksonville 20 kilometers beyond Savannah. If each adjacent pair of named **places** is directly connected by a **link** that the force owner is authorized to use, the route can be said to be *fully specified* and will be used exactly as stated. But if any pair of **places** is not directly connected, the JICM Force model will use the shortest feasible route between those two **places**. *Feasible* means along **links**

whose current controlling government allows use by the force. Shortest distance currently is according to the algorithm for solving the dual variables of the transportation problem.[5] Such a movement can involve only one strategic leg, i.e., one airlift or one sealift.

The JICM 1.0 path display can be used to find out exactly how either a specified **ground force** or a hypothetical force starting at a specified **place** would be routed for any deployment the user specifies. This display includes information on whether current ally or enemy control permissions[6] make the deployment completely impossible. More significantly, JICM Map can be used to view maps of all land geographic features being simulated, as shown in more detail in Section 4.

Variable Resolution of Land Geography

The JICM 1.0 land network data base is extensive: About 900 **places** are defined and over 2,000 **links** describe the surface connections between pairs of **places**. This does not mean that the world surface network is modeled at equal resolution everywhere. The network is designed to service varying model needs, and it is a variable-resolution design to the extent that the data provided can be very simple or very complex, as the analyst's wants or needs dictate. For example, where the network must support an ITM combat modeling adjudication, it can be made as detailed as potential maneuver plans dictate. The JICM 1.0 network defines over 90 **places** and 140 **links** just in North and South Korea to support expected ITM scenarios there. Where only surface mobility need be simulated, a less-detailed network suffices. For example, the data for the continental United States has only about 65 **places** and 120 **links** to approximate the interstate road and rail networks across which strategically deploying forces would move. Finally, where analytic interest is trivial (accounting of forces only), the network can be sparse. Thus, each African **region** (other than Egypt) contains only one or two **places**, and the **links** among them are sparse.

Maritime Networks

The JICM sea **regions** are organized according to their location into five major groupings, called "sea-beds." They are North-Atlantic (all maritime areas north

[5]See, for example, Harvey M. Wagner, *Principles of Operations Research, with Applications to Managerial Decisions* (Englewood Cliffs, N.J.: Prentice-Hall), 1969, pp. 231–235.

[6]If a force lacks required permissions for overflight, refueling, or ground transit, the deployment may not proceed.

and east of the Greenland-Iceland-UK gaps, including the occidental parts of the Arctic Ocean), Atlantic, Mediterranean (including the Black Sea), Indian (including the Red Sea and Persian Gulf), and Pacific. In data file maritime.unc, two levels of maritime movement networks are defined in terms of these sea-beds.

A global-level network (routes) connects sea-beds by specifying all possible ways to get from each sea-bed to each other sea-bed. Every point where sea-beds intercept others occurs at a named global choke-point **region**. For example, the Atlantic connects with the Mediterranean at Gibraltar. A global sea route is thus nothing more than a sequence of global choke-point regions. For example, one route from any **region** in the Indian to any **region** in the Atlantic might simply be stated as "SuezCanal Gibraltar." However, not all global routes are accessible to all ships. For example, there are restrictions for ships transiting the Panama and Suez Canals, as well as for use of routes across the Arctic Ocean. There are about 60 routes totaling about 125 nodes in the global maritime network.

Local-level networks (routes) are defined to connect **regions** within a sea-bed. These are more complex than global routes and consist of sequences of specific transition nodes between adjacent sea **regions**. A *transition node* is a precise maritime position or choke-point **region** that must be crossed during a move between **regions** (e.g., from the SicilianStrait to MidMed at 35N 15E, or from the PersianGulf to the OmanGulf via Hormuz). For each sea-bed, the local routes must obviously define a way to get from every **region** to every other **region**. There are 80 routes totaling almost 700 nodes in the local maritime network.

Seaport **places** are connections between land and sea **regions**. Each seaport has a *transition position* (where ships leaving the port enter the sea **region** network), which may be specified by the user and, if not, is calculated by the input processor.[7]

Thus, four types of sea movement are simulated in the JICM:

- Movement between dockside and transition position is along the great circle (distance) from the seaport **place** position to the transition position.
- Movement between two positions in a normal sea **region** is along the great circle between the positions. But if it is a choke-point **region** and the positions are on opposite sides of the centroid position, movement is on the great circle from origin to centroid, then from centroid to destination.

[7]The input processor calculates this entry point by looking at the latitude and longitude grids immediately adjacent to the seaport location, starting at the grid north of the seaport and moving clockwise, until a sea region is found.

- Movement between **regions** in the same sea-bed is along the shortest local route that connects the **regions**. These routes are explicitly defined in the data base.
- Movement between **regions** in different sea-beds is along the shortest feasible route that connects the sea-beds. Here, *feasibility* refers to ship capability to negotiate the global choke-point **regions** (for example, some ships are too large to transit the Panama Canal).

Seaboxes

Each sea **region** can be overlaid with a grid consisting of one or more named **seaboxes** (names are constructed from the name of a sea **region** and an index number, such as GIGap/12 or GulfMex/7). A **seabox** is a rectangle (with sides defined by specific latitude and longitude coordinates) that overlays at least some portion of the sea **region** for which it is named (it may include islands and land near coastlines), and that does not overlap any other **seabox**. The parallels and meridians that form **seabox** boundaries cannot be any more highly resolved than a tenth of a degree. Over 1,200 **seaboxes** are defined for JICM 1.0 in data file maritime.unc. They are similar to the original patrol boxes first included in Global 89. They do not cover all the sea **regions** and are under review.

The concept of patrol areas is new in JICM 1.0. A *patrol area* is an aggregation of one or more seaboxes is which a ship or maritime patrol aircraft (MPA) unit searches for opposing ships. It is defined using the Patrol order.[8]

Ship Routing

As with land routing, the JICM user has complete control over ship routing if that is desired. The Route order permits up to 20 intermediate instructions that can be used to specify precisely how a ship (or group of ships) proceeds. Each instruction can be either the name of a seaport **place** (e.g., Norfolk), the name of a sea **region** (e.g., GIGap, meaning the exact centroid of the region), a position in a sea **region** (e.g., WMed>40.2N5.0E), or the name of a **seabox**. The route display at the Force window allows a user to test ship routing orders, seeing when ships will arrive at each specified position if a Route order stating those positions is given.

[8]Within JICM, a *command* is an instruction given at the model interface. One type of command is an *order*, which directs actions (e.g., deployments) by one or more governments, or one or more commands.

Data Duplication

During the development of the ITM and its graphics packages, much progress was made in eliminating duplicate (and potentially conflicting) geographic data. Prior to ITM development, there were *no* shared geographic data among the JICM-A models, the JICM-C models, and the graphics. As of the JICM 1.0 release, the status of common geographic data among these models is as follows:

- Names of **regions** are defined separately in the JICM-A (as value types), in the JICM-C (as part of the compiled code), and in the graphics. The precise borders of **regions** are needed only by graphics and are defined there only. Because the structure of the **region** layout is such a basic feature of the geography and so much else is dependent on this structure's being precisely correct, it is not currently considered desirable to make that structure changeable by all users.
- All **place, link**, and **terrain** data are defined only in the JICM-C data files. The JICM-A and JICM Map get the data only from the JICM-C. A network seen in the graphics is thus guaranteed to be the same as the one being simulated in the JICM to which the graphics is attached.
- All maritime **seabox** data are defined only in JICM-C data files. JICM-A and JICM Map get the data only from the JICM-C. A naval overlay seen in the graphics is thus guaranteed to be the same as the one being simulated in the JICM to which the graphics is attached.

4. ITM Ground Force Operations

Bruce Bennett[1]

The JICM Integrated Theater Model (ITM) of ground combat is new in JICM 1.0. This section introduces ITM ground combat. It begins with a general description of the ground combat model. It then describes the inputs required to run the ITM ground combat model and the outputs generated by the model. It concludes by discussing known model limitations and plans for future enhancements of the model.

Summary

ITM focuses on the operational level of warfare: It assumes that the user is operating from a theater commander's perspective and expects user inputs at that level. Ground forces are depicted at a level of detail appropriate for this view (divisions and independent brigades, which are in turn subordinated to corps and army commands). ITM includes internal models (such as the LOC Commander) to handle lower levels of decisionmaking, although in many cases it provides the user the option of overriding these models and directing specific actions. However, simply by aggregating the entities followed into divisions, much of the tactical detail of ground combat is abandoned, in part to encourage the proper perspective by users.[2]

At the same time, the model includes far *more* detail than has been customary in many other theater-level models. For example, in employing forces, it considers characteristics such as nationality, cohesiveness, composition, and level of training. Units may be given specific missions (e.g., dig in as a reserve at a particular defensive position in the rear or spearhead an attack on the enemy). It also allows the analyst to vary assumptions about a broad range of qualitative and quantitative issues, such as national fighting effectiveness, maximum combat intensity, the intensity of sustainable combat, exchange ratios while fighting in prepared defenses, effectiveness of close air support and helicopters in imposing

[1]Others assisting in this effort were Daniel Fox, Barry Wilson, and Carl Jones.

[2]As noted in Section 2, there are tactical and operational discontinuities in warfare that are often ignored in modeling and analysis. Our design for the JICM has specifically placed us on the operational side of these discontinuities to avoid as often as possible the difficulties they present.

attrition and delay, defensive strategy, attacker strategy, and (scripted[3]) surprise and chemical effects. Ground combat adjudication is a mixture of weapon-on-weapon calculations (for attack helicopters, artillery, and air defense) and force-on-force calculations, the latter reflecting aggregate equipment as well as various personnel and tactical or operational factors.

ITM is specifically designed to allow the user to examine operational-level maneuver. The JICM network facilitates such examinations, making it possible for forces to come into contact in various configurations. ITM command mission orders allow the user to direct the maneuver of ground force commands and to designate main thrusts from supporting or holding actions. Counterattacks, envelopments, flank attacks, and other kinds of engagements are explicitly provided. The concept of *phases of battle* (preparation, assault, breakthrough, and exploitation and pursuit) is also especially important to the treatment of maneuver. Without it, it is virtually impossible to understand the results of historical battles or even to produce battles in which the overall exchange ratio does not strongly favor the defender. The model predicts breakthroughs and assesses a combination of (1) increased losses until the recovery of the defense, and (2) a local one-time loss to the defender under conditions for which such breakthroughs traditionally have occurred—where the density of defending forces is too low, where a static defensive line is penetrated, or where an infantry force with limited mobility is overrun. The ultimate effect of a breakthrough depends on whether the defender can bring sufficient operational reserves to bear to contain the breakthrough. The density of forces is also important in many of the other rules of combat adjudication.

Finally, the model allows the user to "script" a number of events, such as damage to specific forces and covert mobilization and/or training. For example, the user can decree that a unit will suffer 5 percent attrition because of unmodeled mine or chemical effects. Alternatively, the user could "kill" 5 percent of the strength of a division in South Korea or transfer 60 tanks into a Marine division in Saudi Arabia from a reserve Marine unit in CONUS. These options allow the user to account for issues that the model might otherwise miss, or to simply test the sensitivity of outcomes to events that could occur.

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[3]By *scripted effects*, we mean effects that are estimated off-line and then inserted into the system. Since the JICM lacks a detailed model of chemical effects, the user must determine off-line the likely effects of a chemical strike, including how the chemicals would be delivered, how much could be delivered, how well prepared the defenders would be, how the chemicals would affect the defenders' ability to fight, and how long such effects might last. These effects can then be "scripted" into CAMPAIGN as a degradation in combat effectiveness over a specified period. Many other factors may be similarly scripted.

The ITM ground combat model can be described according to its five basic components: (1) the objects represented, (2) ground force command and control, (3) the interactions between commands and units, (4) battles, and (5) support issues. We describe each component in turn, focusing on a Korean example that was used to support ITM development.

Ground Combat Objects

Section 3 describes the basic geography implemented in the JICM. The networks it describes were developed, in part, to directly support the ground combat model. The ITM ground combat model assumes that all ground force operations occur along a network such as the one shown in Figure 4.1. The places and their links, which constitute this network, are defined in input file place.unc. There is as yet no on-line procedure for modifying the network; however, it is simple to

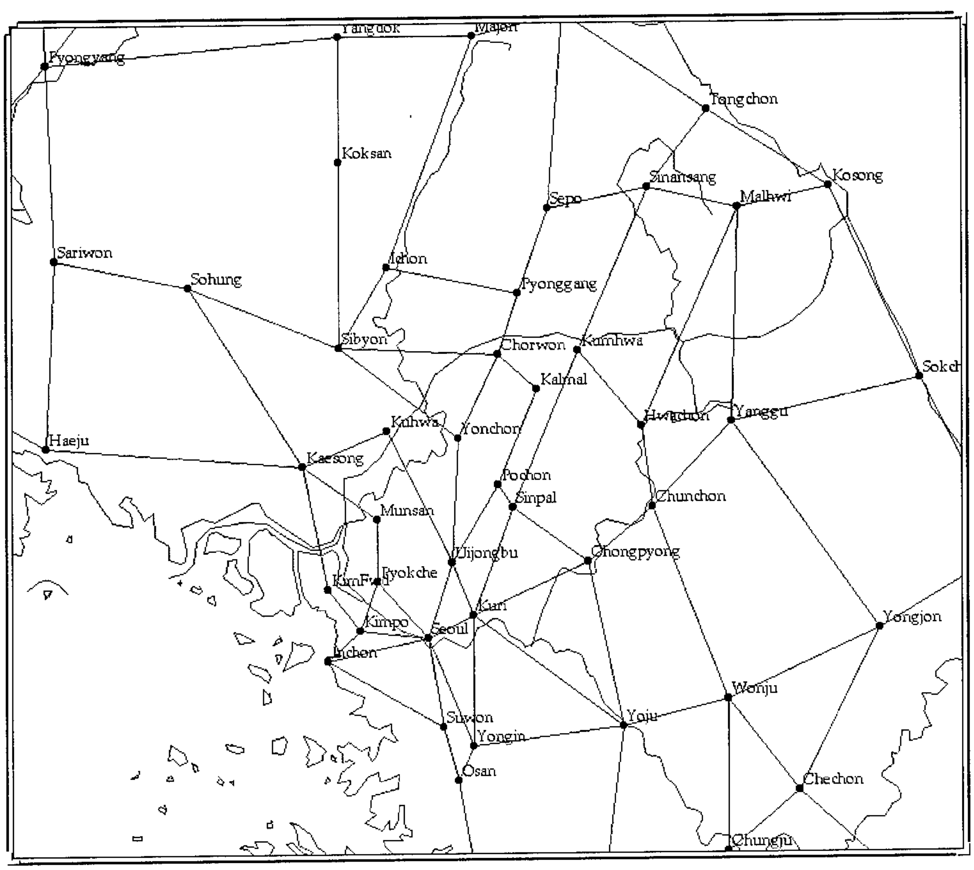

Figure 4.1—The Korean Network

modify place.unc to add places and links between them, then rerun the input processor to be able to use the modified network.

To perform ground combat adjudication (i.e., assessment of the results of ground combat), the network must be overlaid with a description of the terrain. By default, all links in the network are considered to be 20-kilometer-wide "mixed" terrain. The terrain parameter (see the discussion of inputs below) allows the user to define other types and widths of terrain, and to break links into component pieces by type of terrain, as shown in Figure 4.2 (defining open, mixed, rough, mountain, urban, and river terrains). The minefield parameter also allows users to establish minefields in any of the component pieces of the link.

Ground force units are the basic force entity used by the ITM ground combat model. ITM normally works with divisions of combat forces and independent brigades or regiments of maneuver forces, artillery, and attack helicopters. These units are defined in input file ground.sec. A unit is described by the factors shown in Figure 4.3 (and by other factors; this figure results from the instruction "display find 5-CORPS/5-ARTB SKorea"). This description is much expanded from that in the RSAS. With ITM have come the expansion of the weapon

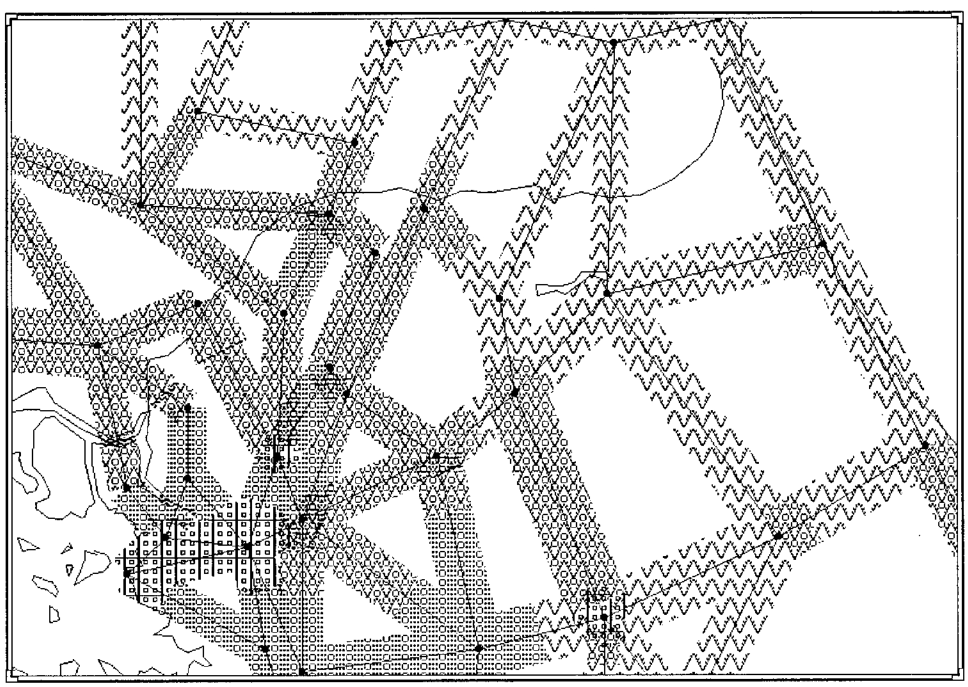

Figure 4.2—Terrain Around the Korean DMZ

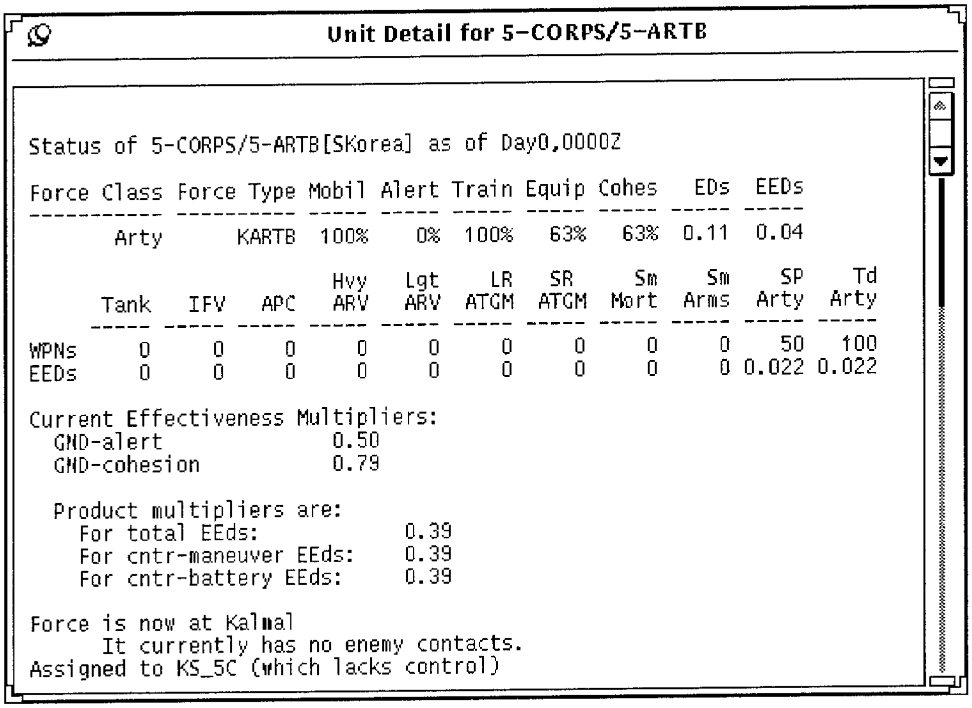

Figure 4.3—Describing a Ground Force Unit

categories to 16 (the 11 shown here plus attack helicopters, two kinds of air defense weapons, and two kinds of long-range artillery systems) and the change to a RAND-developed ground force scoring system used to calculate the equivalent divisions (EDs) of a unit.[4]

Ground force commands are simply JICM commands used to support ground combat. JICM commands are described in more detail in Section 9. The character of ground force commands is illustrated in Figure 4.4.[5] Ground force units are assigned to ground force commands and usually assume a mission within the command, such as a front force, a reserve force, or a reconstituting force. Ground force commands have a path designated across which they will move on the network, as shown in Figure 4.5; they are oriented on this path (given a direction to face) and may have a designated mission to execute along this path. Once oriented, a command is described as an arrow on the JICM Map graphics, the head of the arrow showing the orientation and the tail of the arrow

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[4]This system is documented in unpublished RAND drafts. See Appendix B for a definition of EDs and effective equivalent divisions (EEDs).

[5]In JICM 1.0, the most forward line of own troops (MOFL) and the control line (CONL) of a ground force command are treated as collocated.

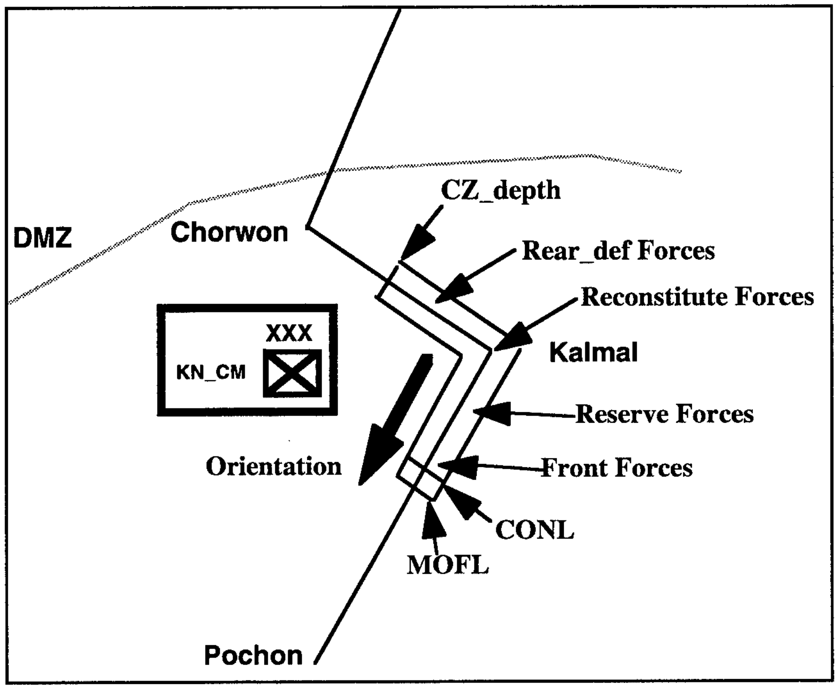

Figure 4.4—Ground Force Commands

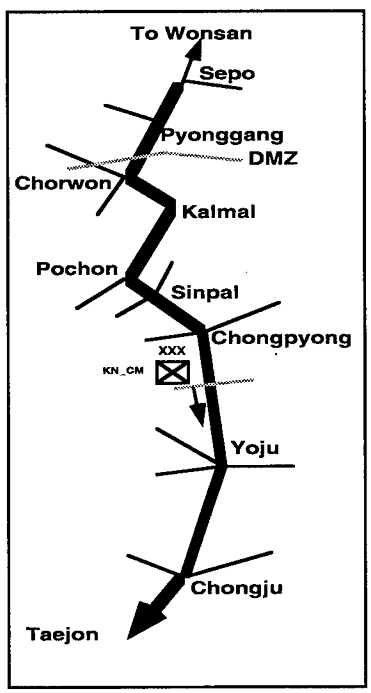

Figure 4.5—A Ground Combat Path

showing the command's *depth* (i.e., the distance from the front to the rear of the command). A ground force command cannot operate on two paths simultaneously, except where paths overlap.[6] Ground force commands can also have defined parameters that are different from the parameters of other commands, based on the assumption that combat and other operations may differ from one combat sector to another.

ITM assumes that the front of a command is not a simple concept. As suggested by Figure 4.6, the front has a forwardmost position (the MOFL, or most forward line) and a position to the rear at which it has complete control (the CONL, or control line). In between the MOFL and the CONL, the front is nonlinear. Although this difference is a clear part of the ITM design, JICM 1.0 assumes that the MOFL and CONL are collocated. If future JICM development is funded, we plan to implement logic for separating these two lines.

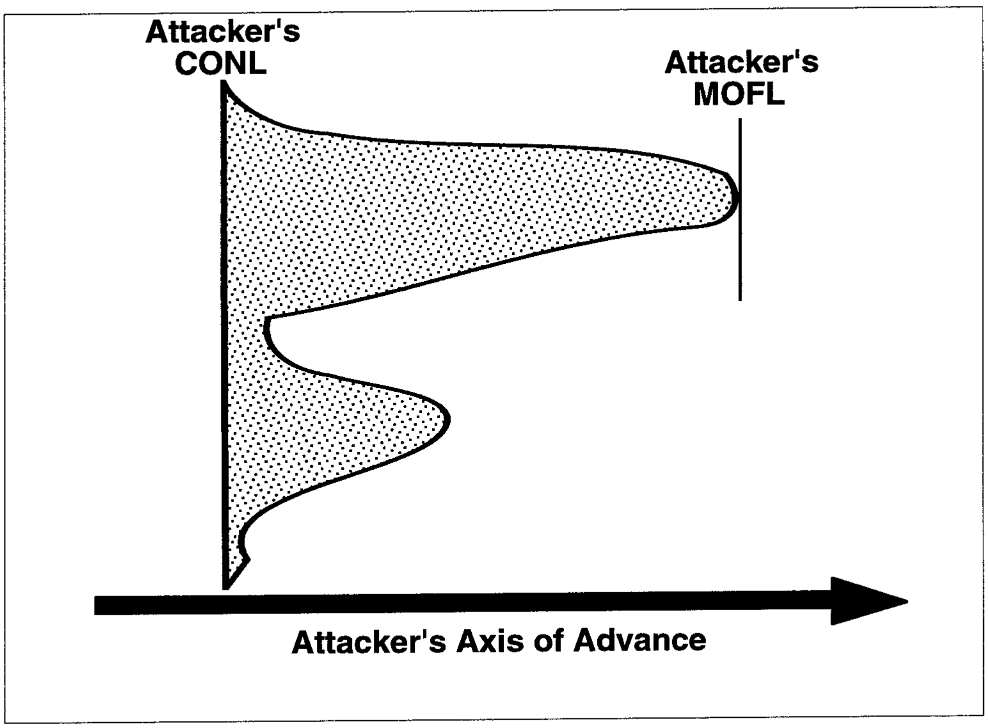

Figure 4.6—Defining the MOFL and the CONL

[6]However, a command may have two or more subordinate commands, each of which operates on a separate path.

Ground Force Command and Control

In ITM, ground force units and commands may move freely across the network; there are no permanent "axes" or "avenues of advance" (as existed in the former CAMPAIGN-MT and CAMPAIGN-ALT models) to funnel movement. For example, in Figure 4.7, command KN_CM may be advancing toward Sinpal but runs into unexpected resistance; if command KN_5E reaches Sinpal first, it may be routed toward the front of KN_CM to destroy the intervening enemy forces.

The ground force commands are given missions to control their operations. Table 4.1 lists and describes the various missions for commands and their state of implementation in JICM 1.0. The "join-atk" mission is the one that would be given to KN_5E in Figure 4.7 to have it attack until it makes contact with KN_CM. The more-complex missions, which involve putting forces into the rear (air-drop, air-assault, and penetrate), have not yet been implemented, nor has the pass-through mission; otherwise, all planned ITM missions are operational.

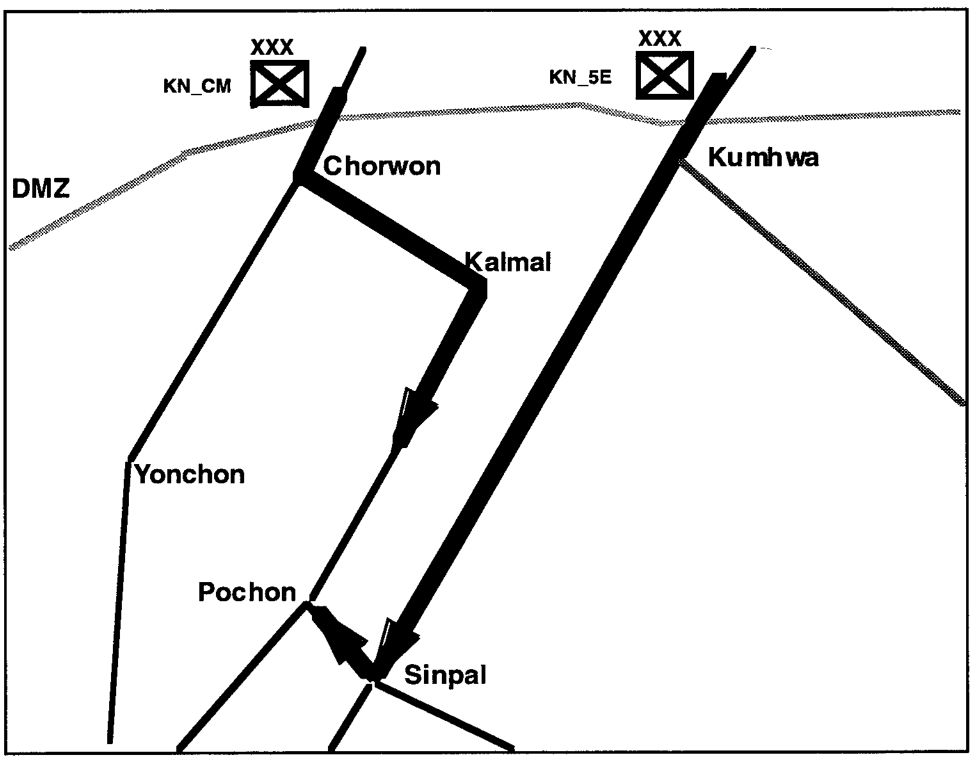

Figure 4.7—Moving Across the Network

Table 4.1

Ground Command Missions

Mission	Status	Function
Normal		
main-attack	Implemented	Main attack sector
spt-attack	Implemented	Supporting attack sector
pin-attack	Implemented	Holding attack sector
counterattack	Implemented	Counterattack
defend	Implemented	Defend through depth of position
defend-delay	Implemented	Defend in prepared positions, then delay
defend-withdraw	Implemented	Defend in prepared positions, then withdraw
delay	Implemented	Delay (do not move back unless pressed)
withdraw	Implemented	Withdraw (move back on own initiative)
positional	Implemented	Defend in predesignated zones
break-out	Implemented	Break out of an envelopment
join-atk	Implemented	Attack until in contact with a friendly attack
follow	Implemented	Follow an attacker as an echeloned force
cancel	Implemented	Cancel previous mission
air-drop	Formatted	Air drop behind enemy lines (not operational)
air-assault	Formatted	Air assault behind enemy lines (not operational)
amph-assault	Separate	Amphibious assault (see Section 6 for procedures)
pass-thru	Undefined	Move echeloned command to the front
penetrate	Undefined	Penetrate opposing force (e.g., an operational maneuver group [OMG])

Ground force units may also have missions, as shown in Table 4.2. These missions allow the user to control the way particular forces are used by a command, to locate a positional defense by a unit, and to manage attack helicopters and long-range artillery.

Because movement is unconstrained by the JICM network, two commands may advance as shown in Figure 4.8. Both commands may have the same designated initial objective (Chongju), after which both are to advance over the same link between Chongju and Taejon, then split and advance separately. ITM allows the user to specify a stopping condition if one or both commands reach Chongju, and to either have the first arrival proceed to Taejon or await the arrival of the other command and then follow it. The call-plan parameter setting described in

Table 4.2

Ground Unit Missions

Mission	Status	Function
Normal		
front	Implemented	Put unit at the command's front
reserve	Implemented	Put unit in the command's reserve
reconstitute	Implemented	Put unit into reconstitution
position	Implemented	Establish a positional defense
helo-support	Implemented	Support a friendly command with attack helicopters
helo-strike	Implemented	Strike an enemy command with attack helicopters
arty-support	Implemented	Support a friendly command with long-range artillery
arty-strike	Implemented	Strike an enemy command with long-range artillery

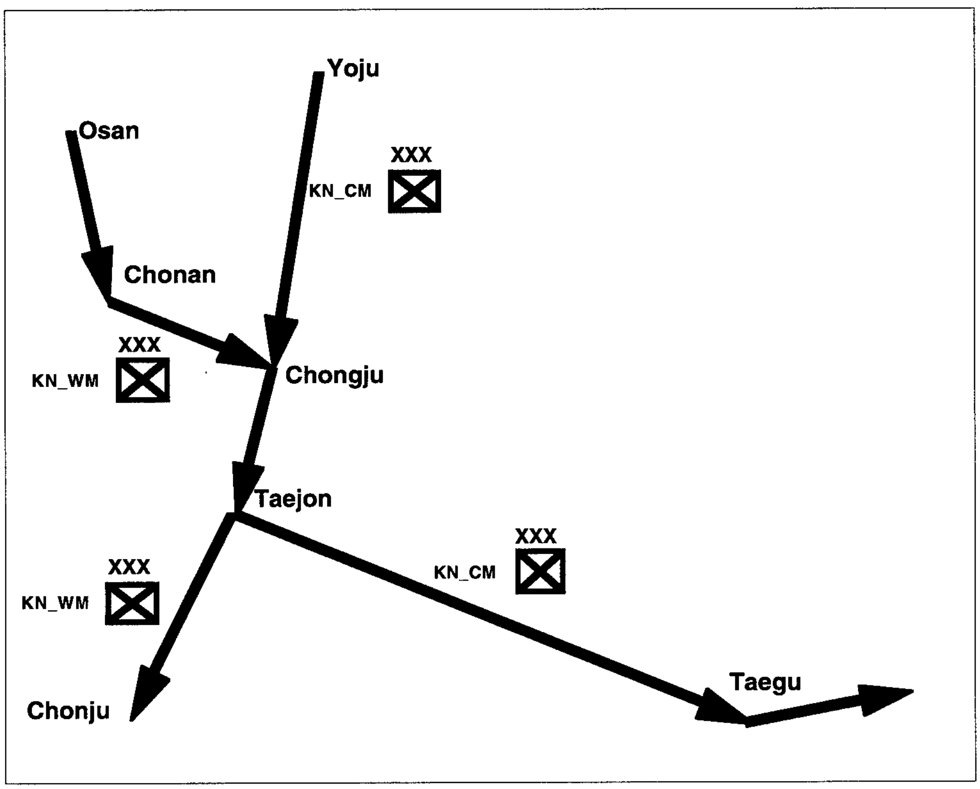

Figure 4.8—Commands Merging and Moving Across the Network

the subsection "Plan Directory Files" allows the user to determine which force proceeds first.

The concept of positional ground force units and commands is unique to ITM. It reflects the fact that in many parts of the world, ground combat units have very limited mobility and are essentially assigned to defend a given piece of terrain (and not to fall back when pressed by an attacker, as in the former Central European paradigm). In ITM, any unit can be put into a positional defense; units not in positional defenses normally deploy to the oriented position of their command (into a front, reserve, or reconstituting location or role). Thus, as a command advances, forces may be positioned in its rear to cover it against flank attacks. Although positional units do not advance, they may move backwards (if pressed) up to a specified rate per day (which may be zero), reflecting the mobility of the unit and its intended employment. If an attacker advances past the rear of a positional unit, the positional unit is assumed to be overrun and to suffer an attrition penalty, although in most cases continuing to survive at a reduced level of cohesion in the rear area of the attacker. The attacker must then allocate some of its forces to isolating and "mopping up" the enemy force in its rear; the enemy force continues to fight until it reaches a designated level of strength that is insufficient for it to continue to exist.

By extension, a positional command is made up of a series of positional units. Whereas normal ITM ground commands have a specified depth, positional commands have their depth defined by the location of the positional units along their path. If all the units in a positional command are overrun, the command is considered to be overrun, although it may still function in trying to disrupt the rear-area operations of the opposing attacker.

For oriented commands, the choice of which units will operate at the front must be handled regularly throughout the campaign: As one unit is severely damaged, it needs to be withdrawn and replaced by a reserve force; the withdrawn force needs to reconstitute equipment, personnel, and cohesion. The ITM LOC Commander determines when to change these force roles, unless the user chooses to do it using the ground mission orders. It also determines when units are ready to be returned to reserves or committed to the front.

As an attacker advances into a defensive position, the relative command, control, communications, and intelligence (C3I) of the defender makes a considerable difference in the opposition the attacker faces. A defender with good C3I will be able to redirect fires against the penetration, move unit boundaries, and commit reserves at various echelons. If the defender has poor C3I, the attacker may face

only limited opposition after penetrating the front lines (as often happened in the Persian Gulf War). These details are at a tactical level and yet real—they actually occur; therefore, ITM includes a model to reflect these phenomena, as described in an *RSAS Newsletter* article.[7]

As a command advances, it has historically been the case that models such as the JICM assumed that all the forces in the command advanced in step simultaneously. In many theaters, this may be possible for very slow advances, but for faster advances (more than a few kilometers each day), the command will begin to string itself out along the road network. Thus, an attacker that breaks through a defensive line and then must advance 50 kilometers to make contact with an enemy force in prepared defenses will find that only a small amount of its combat power makes the initial contact with the subsequent defensive line, and it is therefore unable to make an assault on this line unless the opposing force is in a state of disarray. Rather, the attacker must wait for its component units to arrive forward and make preparations for an assault. JICM 1.0 has a model within it to deal with these phenomena, giving proper advantage to a defensive position that is arrayed and prepared before an attack.

Contacts and Other Interactions

In ITM, land combat is fought between opposing columns. A *column* is a located and oriented collection of one or more ground units and is classified as either simple or complex. A *simple column* consists of just one ground unit. A simple column is generated by every ground unit that has a positional mission, and by every other ground unit that is not currently located within the limits of its assigned command's orientation. A *complex column* contains one or more ground units, and such a column is generated by every oriented command. Its forces consist of all assigned units that have not generated a simple column as just described.

There is absolutely no limit to the way that friendly columns can overlap. Thus, any number of friendly columns can occupy the same space, with partial or complete overlap, and with the same, opposed, or oblique directionality. Complex columns can overlap simple enemy columns (as when an attacking command overruns a defending positional force, or an airborne force is inserted into an enemy command's orientation), but complex enemy columns can never overlap each other. However, they can contact (abut), and where they do make contact, ITM battles are adjudicated.

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[7]Bruce Bennett, "Ground Combat C3I Effects," *RSAS Newsletter*, January 1992.

A column has five possible contact locations: front, rear, flank, inside, and surround. The last two involve the contact between a complex column and any simple columns that are totally within the complex column's area (the complex column "surrounds" the simple column "inside" of it). Not counting such overruns, Figure 4.9 shows the five basic kinds of contacts that ITM deals with. The most common kind of contact is a front-to-front contact, in which commands meet head-on and have a direct battle. The next most common type of battle is a front-to-flank battle, in which an attacker hits the flank of an opposing force; the flank contact generally gives the attacker an advantage in the resulting battle (the opposing force usually suffers some degree of surprise, and, unless it has adequate C3I, may face a real problem in responding to the flank attack). The contacts with the rear are less common but can happen, especially when commands are enveloping opposing forces.

Note that the attacking force must always be an oriented command, but the opposing force might also be a positional unit or a unit otherwise caught away

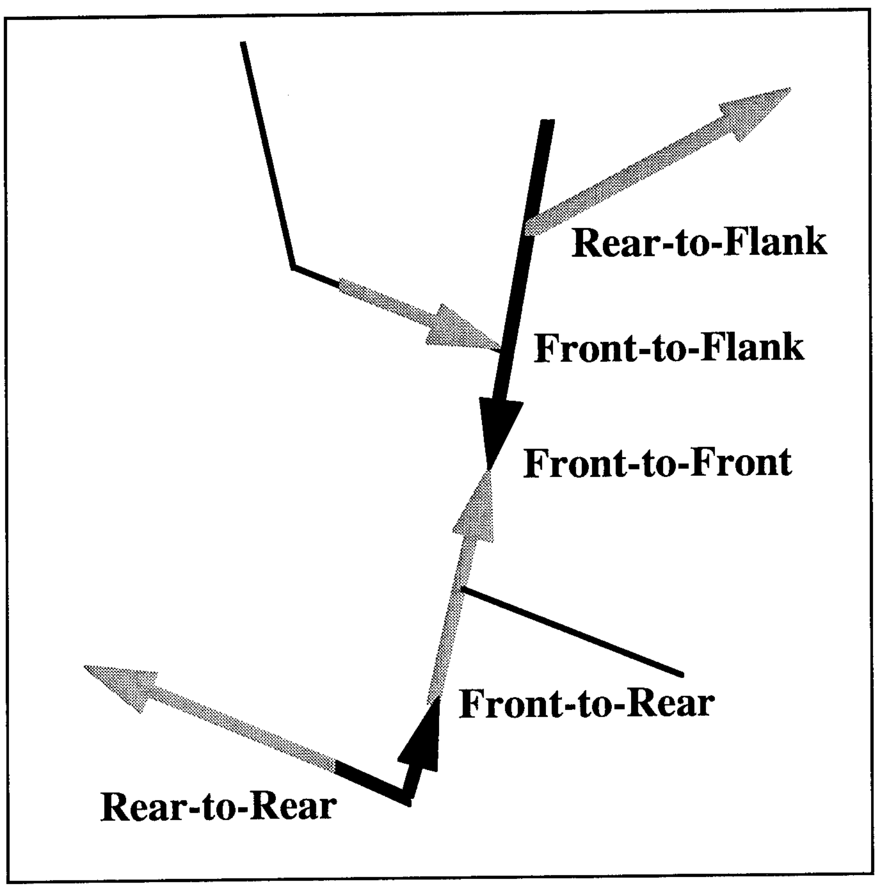

Figure 4.9—Ground Contacts

from its command. ITM allows for separate contacts between commands and opposing units.

When a contact occurs, a battle develops. The battle is characterized by the commands or units involved, the units within those commands, the type of contact, preparations by the defender and the attacker for the battle, the terrain characterization, and a large number of parameters on each side. A given command may be involved in more than one battle at a single time, in that it may face one or more enemy commands at its front, one or more on its flanks, and opposing forces in the rear. These conditions are separated into distinct battles, because the character of battles associated with the differing types of contacts is not the same. Thus, it would be a mistake to argue that a flank attack should simply be combined with an ongoing frontal attack for combat adjudication.[8] Figure 4.10 shows how a part of the theater might thus appear, with the arrows representing commands on each side and the stars representing ongoing battles.

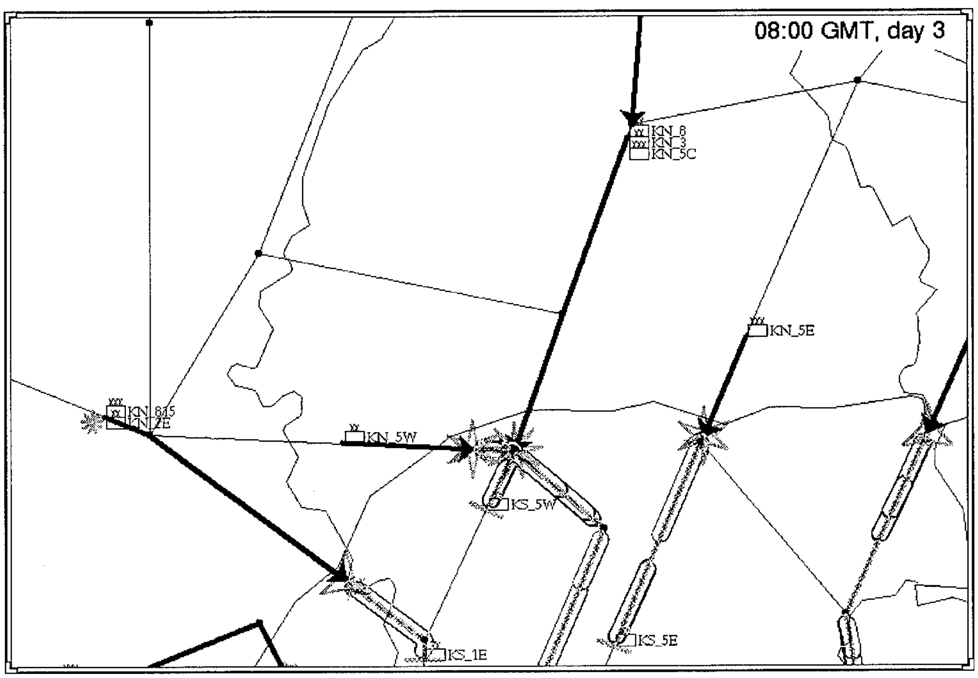

Figure 4.10—State of the Battlefield, with Multiple Battles

[8]See the discussion of this issue in Patrick D. Allen, "The Need to Represent a Wide Variety of Battle Types in Air-Ground Combat Models," *Military Science & Modeling*, May 1993, especially pp. 14–15.

There is one limitation in contacts in JICM 1.0. In many cases, the real objective of a flank attack is to sever the opposing command into two parts. There is no easy way in ITM to so cut a command; for now, when a flank attack occurs, the attacker is presumed to be held in place (it cannot advance), although the attrition that would otherwise be calculated from a flank attack is determined, and, once this attrition sufficiently affects the opponent, the opponent usually must withdraw and allow the flank attacker to begin advancing again. The defender will also withdraw forces from the front to help cover the flank, which may allow the frontal attack to proceed more rapidly. We are contemplating other procedures for handling this problem, and are open to suggestions.

It is also possible for units to engage each other in combat, even when they are not directly in contact. JICM 1.0 allows three kinds of out-of-contact attacks by ground forces:

- All ground force units that are not in direct contact with an enemy force may fire their artillery at any ground force forward of their position along their path, out to the maximum range of the artillery. This situation handles the case of an attacker trying to cross a demilitarized zone (DMZ) to make contact with the defender, and being opposed by artillery fire in the process.
- Long-range artillery (such as ATACMS) may be fired at any enemy force within range of the artillery (whether on its path or not).
- Attack helicopters may also be flown against any enemy force within range of the helicopters (also without regard to the path of the command containing the helicopters).

In addition, air forces may strike any opposing force, whether or not in contact with a friendly force.

Battles

Battles are adjudicated according to the format shown in Figure 4.11. This figure shows the battle display as it is generated from the JICM Map graphics. The initial lines of the display indicate the timing of this part of the battle and the commands and/or units involved. The next several lines provide a characterization of the battle and a summary of some of the key measures of the battle. The next two lines indicate the kind of contact for each side and the missions and strategies of the sides. The display then gives a summary of *shoulder-space limits* (i.e., limits on the ability of forces to fit on a given terrain), as well as constraints on the forward movement of forces. The equivalent division summary is followed by the artillery fire suppression effects and the calculated

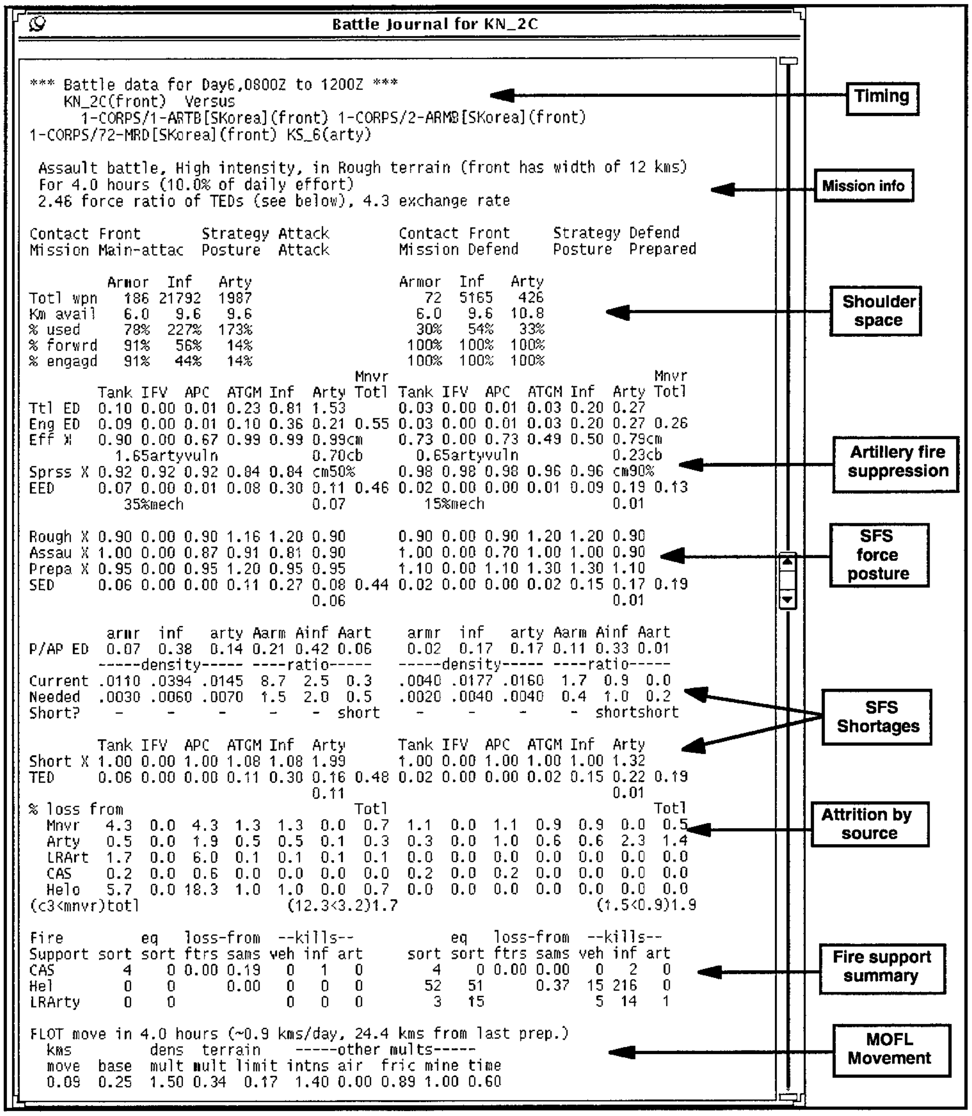

Figure 4.11—The Battle Display

effective equivalent division (EED) score in each of the six aggregate weapon categories shown. The SEDs (situational equivalent divisions) are then calculated according to the Situational Force Scoring (SFS) methodology adjustments for terrain and force posture.[9] The TEDs (tactical equivalent divisions) are calculated according to the Situational Force Scoring shortages methodology.

[9]Patrick D. Allen, *Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models*, RAND, N-3423-NA, 1992.

The figure next shows percentage losses to each weapon type by source of loss, describes the air and/or ground interactions, and presents the forward line of troops (FLOT) movement results.

Conceptually, these calculations derive from a framework like that shown in Figure 4.12. In it, the type of contact (e.g., front-to-front), the character of the battle (determined by the current activity of each side and the preparations that the defender has made), and the nature of the environment (the type and width of terrain and any placement of mines on the battlefield) are inputs to the combat adjudication.

The first stage in combat adjudication is the calculation of fire support effects coming from tactical aircraft (close air support [CAS] and battlefield air interdiction [BAI] missions), attack helicopters, and artillery (to include in-contact ground unit artillery, out-of-contact unit artillery, and long-range artillery, such as multiple-launch rocket system [MLRS] and ATACMS); these assessments are done in weapon-on-weapon calculations and determine the kills against opposing forces, the fire suppression effects for the artillery component of the fires, and the effect of these fires on movement. ITM then simulates close combat based on Situational Force Scoring (the Calibrated Differential Equation Methodology [CADEM] weapon-on-weapon option is not yet ready for JICM use), determining the kills achieved against the opposing forces and the

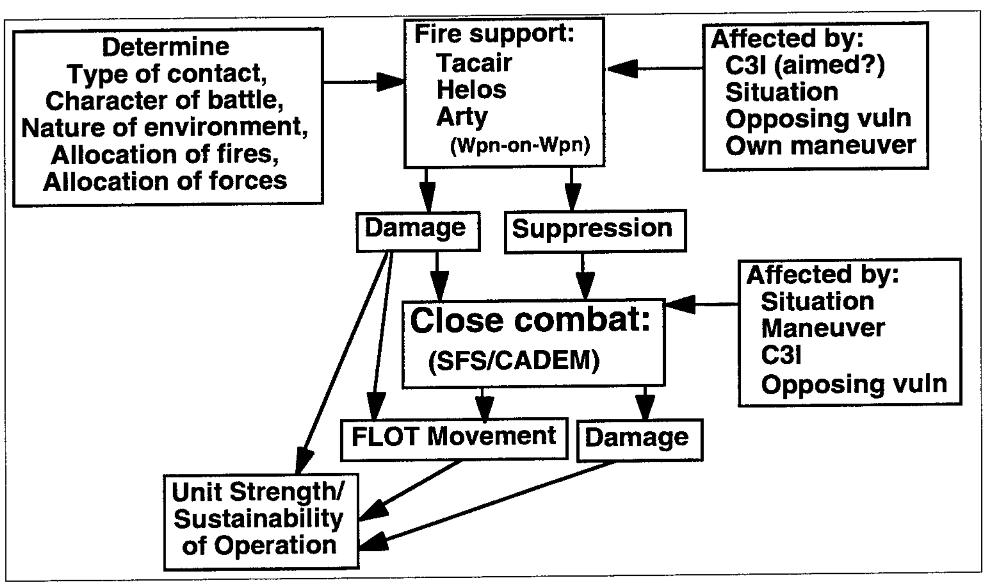

Figure 4.12—The Framework for Ground Combat Battles

movement of the opposing forces. Kills and movement, in turn, determine the strength of units and whether specific operations (whether attacks or defenses) are sustainable.

Support

ITM takes advantage of the models of lift and logistics described in Section 7. The model tracks days of supplies for ground forces by nationality and permits optional sharing of supplies among allies.[10] Movement of supplies can be ordered or scripted. War reserve materiel (WRM, e.g., spare tanks) may be provided as data, and stocks of equipment, such as POMCUS (prepositioning of materiel configured to unit sets) and MPS (maritime prepositioning ships), may also be entered. Damaged weapon systems are repairable, and items repaired at theater level are added to the WRM.

Segments of the network are characterized by trafficability and LOC vulnerability, and movement of individual ground forces through each segment can be reduced by a level of interdiction reflecting the LOC vulnerability, as well as by scripted refugee congestions. A notional logistics tail, or "log tail," is identified that tethers the ability of an attacker to advance and provides a key target for defending systems to interdict.

Implementation

JICM ITM has been developed using a combination of C language code and RAND-ABEL in the form of C-ABEL (see Section 8 for more details). The C code is used to support basic accounting functions, which are more efficiently done in a language like C. The C-ABEL code defines most of the actual combat interactions. The advantage of this implementation approach is that JICM users can easily alter the C-ABEL code, which is entirely provided with the JICM release, and thus can change the logic behind many of the basic adjudication modules of ITM. Users interested in doing so should refer to Section 8 and also examine the C-ABEL code in the JICM Force-C/Abel directory.

---

[10]Provision is also made for tracking fuel and more-detailed classes of supplies, but RAND has not been able to acquire sufficient and appropriate data in these areas to properly reflect these issues (remembering that for the JICM to properly model an issue, we need to have data for forces of many nationalities around the world).

New in JICM 1.0

The entire ITM model was new at the end of FY92 (although parts were derived from the former CAMPAIGN-MT and CAMPAIGN-ALT models); it was released as part of a test extension of the RSAS, designated RSAS 5.0. Enhancements to the ITM ground combat model completed in FY93 include the following (some of this list duplicates the discussions above, recognizing that some readers will want to read only this subsection):

- RSAS 5.0 lacked a good model for a defense that has a series of ground force units given positional missions, because there is no way to adequately support these units with artillery, helicopter, and air support. To fix this deficiency, the concept of a positional command has been implemented. A positional command's battles are the sum of the battles of all its assigned forces. Moreover, an attacker can make a flank penetration into a positional command. When a unit in a positional command is overrun, a part of its artillery may escape and join the corps artillery unit, while another part of the artillery will be destroyed during the overrun. To differentiate them from regular oriented commands, positional commands are drawn with a modified arrow (with a bar at the rear) in the JICM Map graphics.
- Positional commands may overlap opposing commands, such as when positional forces are overrun or an airborne force is inserted into the rear of an opposing force.
- Out-of-contact artillery fires are simulated in JICM 1.0. For advancing battle objects, a check is made at the beginning of each period to determine opposing forces that may direct out-of-contact fires against them. This artillery is added to the appropriate battles as if it were part of the assets of the forces in contact. If the battle object is the forwardmost positional force of a positional command, it may also shoot any independent artillery unit weapons belonging to its command if they would not otherwise be employed during the time period.
- Most theater-level combat models assume that the forces committed to a given axis of advance all move together. At slow speeds (less than a few kilometers per day), this may be true; but as the rate of advance increases, an attacking force will string out along the roads in the sector of advance, with relatively little combat power at the tip of the forward forces. If such an advancing attacker makes contact with a prepared defender, the forward units will usually reconnoiter the defenders but will not begin a full assault of the defensive positions until more of the force arrives (especially the artillery), which could take hours or days, depending on the previous speed

of advance and the distance that has been covered. JICM 1.0 simulates this process according to the parameters established for the commands, and thus provides an advantage to a positional defender. Note that the other side of this phenomenon is that a defender will also string out in the face of an opponent's advance, causing some defending forces (especially infantry) to be overrun; this process is also represented.

- Two new kinds of contacts have been added to the original three (front, rear, and flank): inside and surround. These contacts involve a positional unit located within a normal command; the positional unit has an "inside" type of contact, and the normal command has a "surrounds" type of contact.
- A completely new model was developed to explicitly represent selected long-range artillery (or other long-range non-nuclear surface-to-surface capabilities) such as ATACMS. Two ground force weapon types are reserved for this function and may be flexibly defined for each specific unit (thus, one unit may have 240-mm MRLs and 210-mm long-range guns, while another may use MLRS for firing ATACMS). These weapons are not included in the ED scores. The fires of these weapons are constrained by weapon range. The loading score given to these weapons determines what is killed by one volley (a *volley* is one gun shooting one load). The killing (and nonlethal effects) of an equivalent standard volley are parameterized and adjudicated exactly as an equivalent standard sortie of CAS, BAI, air interdiciton (AI), or attack helicopters. The user may explicitly target these weapons; otherwise, a Long-Range Artillery Commander module fires these weapons against appropriate targets.
- An extra set of parameters allows the user to define differential vulnerability for artillery in forward shelters around a border as opposed to the vulnerability of artillery once it must displace from such prepared positions.
- The procedures for allocating artillery fire to the countermaneuver and counterbattery functions have been revised and corrected.
- Attack helicopters operate in JICM 1.0 and can attack deep targets.
- A battle allocator has been added to ITM to fine-tune the LOC Commander's posturing decisions. Because ITM follows such units as divisions and corps, it is not uncommon to find a division with multiple contacts at any given time. The battle allocator examines the contacts of such a force and determines how the combat power of the force would be distributed among its various battles.
- Ground force supply consumption and the issuance of war reserve materiel have been made functional in JICM 1.0. Supply is tracked in terms of ED-days of supply (ammunition) except for the explicit munitions consumed by

long-range artillery, and the per-sortie munitions of attack helicopters. A more-sophisticated set of consumption factors (than in CAMPAIGN-MT or CAMPAIGN-ALT) is included in ITM because of the new battle types that are possible. Each unit has an inventory of supplies and receives resupply as required. Resupply may be interdicted. A notional log tail has been created to limit the ability of an attacker to outrun its supply line.

- The models that allocate the fires of tactical aircraft, attack helicopters, and long-range artillery have been modified to make these processes consistent. The focus of targeting has been shifted to identifying an enemy force, rather than purely to supporting a friendly force. Several parameter names have been changed to enhance clarity. Enhanced log statements are provided to allow the user to follow the results of these calculations.
- The ability of fires (especially CAS and BAI) to affect the movement rate of an attacker is a function of the defender's ground-to-air C3I system. It reflects the reality that air kills must be made in the proper places (where breakthroughs are developing) in order to have the maximum effect.
- Fires incur decreasingly marginal returns, since some fires will be directed against targets that have already been killed. A parameter is set to determine the fraction of already-killed vehicles in a unit that may still be mistaken as viable targets for fires.
- An enhanced set of log file messages for fires allows the user to more clearly follow which fires are causing damage to specific units, and to determine the effects of targeting and attacks.
- The ability of forces to move in various types of terrain has been made a function of the degree of mechanization of the force. Mechanized forces have high movement rates in good terrain, but they suffer serious movement degradation in mountainous terrain; infantry forces move much slower than mechanized forces in good terrain, but their rate of advance is not affected nearly as much in mountainous terrain.
- Rather than have a velocity increase linearly until it reaches a maximum possible velocity, then move flatly at that rate thereafter, velocity approaches the maximum possible velocity asymptotically.
- Refugees can affect the ability of forces to move across certain parts of the network. If a link is specified as having a high degradation because of refugees, units will, at best, be able to move very slowly over that link.
- A simple model of broad-area minefields (such as the area of the Korean DMZ) was added.

- A capability was added to invoke a cease-fire between opposing ground force commands.
- A capability was added so that forces approaching an enemy unit during administrative deployments attempt to find a safer route.
- A procedure for automatically updating the JICM Map graphics at specific time increments has been added, and the update procedure is protected so that the model is not allowed to advance and change basic data before a full graphics update is completed. Thus, camper and JICM Map can now be synchronized.
- Mobile missiles are now represented by unit and in a way that will allow them to be deployed like ground forces. This means that a missile unit can be positioned at any location on the JICM network. The location of missiles can be displayed on JICM Map, and unit details can be accessed. Missile units may be explicitly targeted.
- Ground forces can be scripted into existence, and they can be moved by a script. Deploying forces can have their movement terminated.
- The time required to alert a unit may be set by a script.
- Ground forces arriving in a theater require both unloading time and organizational time in order to be able to move forward and be employed. A similar organization time is required after *any* deployment. These times have been incorporated in the model.

Defining a Run for Ground Combat with ITM

ITM uses three kinds of input files for ground combat. The first kind is JICM data base files in the Force-C/D directory that specify order of battle and weapon data, and become part of the JICM data base. The second kind is use files stored in the Force-C/D/Env directory and identified as combat environment files, which change the default ITM data into theater-specific data and add critical items, such as LOCs and air defenses. The third kind is normal use files, or scenario files, which are usually included in the Run/Plan directory or some parallel directory under Run. Because these three types of files tend to perform separate functions, we describe each separately.

Data Base Inputs

ITM ground combat uses data base inputs that include the following:

- **Geography.** Data on JICM places and the JICM network are contained in file place.unc. Data on JICM regions are found in file geog.sec.
- **Order of Battle.** Information describing the ground order of battle is found in JICM input file ground.sec. This information includes both a description of force classes (unit types for ground forces) and a description of individual units. Information on weapon storage facilities and materiel storage is found in files facility.sec and materiel.sec, respectively.
- **Weapon Data.** Weapon descriptions are found in JICM input file weapon.sec, and weapon inventories are in file weapon2.sec. Further information about weapon systems is found in files missile.sec (for ground-based missile systems) and ground.sec (for long-range artillery).
- **Supporting Data.** Data defining JICM commands are found in file command.sec. Supporting data on mobility assets are in file mobility.sec.

These data are transformed into the JICM data base format by the "input processor" program; thereafter, many of these inputs can be modified by the procedures shown below.

Environment Inputs

In contrast to the former RSAS theater models, ITM does not read substantial data files to initialize key parameters. Rather, it starts from generic data that are included in the computer code. If, therefore, the warfare environment differs in a theater from a generic definition, or if specific information must be entered (for example, on the character of the terrain in a theater), such data must be input via use files, a control plan, or an Analytic War Plan (AWP). The environment use files, set up in a subdirectory of the data (Force-C/D/Env) directory, are intended to contain this information. The environment use files are designed to be read once at time zero in a simulation (thus setting the required information for the duration of the simulation); the data input here can also be redefined through other inputs at a later time in the simulation, but many of the parameters entered in these files will remain constant.

The environment input files can be flexibly defined, but they are usually set up as follows. If, for example, we will be doing analysis of Korean conflict, the baseline file in the Force-C/D/Env directory will be called "korea" and will look as follows:

```
if kor_env != done
    use Env/korea.geog
    use Env/korea.sam
    use Env/korea.param
    define kor_env = done
endif
```

The if statement here is used to prevent rerunning these files once initialization has been completed. The inputs are divided into four files covering (1) geography, (2) air defenses, (3) parameter settings, and (4) command relationships. Each input file is described in turn.

ITM Geography Inputs. The JICM network defines the basic geography used in each theater in ITM. From a ground force perspective, each part of the network is defined by default as being 20-kilometer-wide mixed terrain. This default setting can be changed by a script such as

```
set landwar-terrain Kuhwa Uijongbu  rough   15   30%   \
                                    river   15   2%    \
                                    rough   12   60%   \
                                    urban   10   8%    end
```

where this instruction divides the terrain from Kuhwa to Uijongbu into four segments. The first, which is 30 percent of the total length of the segment, is defined as rough terrain (the other options are open, mixed, mountainous, urban, and river) that is 15 kilometers wide. Once these values are set, the user is encouraged to display the terrain to make sure that it appears logical.[11]

The geographic inputs next identify named locations that are not at places in the JICM network. For example, the north and south sides of the DMZ in the east Kaesong/Munsan (Uijongbu) corridor might be defined by

```
set loc location  Ndmz.3W     Kuhwa/1.2/Uijongbu
set loc location  Sdmz.3W     Kuhwa/5.2/Uijongbu
```

Thus, the location Kuhwa/5.2/Uijongbu can also be called Sdmz.3W.

Finally, this file is used to set the initial lines of communication (paths) along which commands will operate. Although other paths can be added later, it is usually preferable to specify paths in this file. A path is specified in the following format:

```
set loc path axis.3W kuhwa>uijongbu>kuri>yongin>osan...
```

[11]See Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, MR-122-NA, 1993, pp. 22–25. An updated version of this documentation exists as an unpublished RAND draft.

where this instruction creates path "axis.3W," which runs from Kuhwa through Osan and beyond. Generally, paths are specified to be quite long (well beyond the intended area of ground combat operations) to provide a basis for targeting AI and BAI in the rear of each force. The names of paths are not constrained to be of the format shown here; rather, we use this format to parallel the format used in the historical RSAS models.

Air Defense Inputs. This file specifies the character and location of surface-to-air barriers, area defenses, and point defenses (see Section 5 for more discussion of how these defenses are represented). Barriers are specified between two JICM regions (such as NKorea and SKorea) by a script such as

```
*                          Kill   Surv  # of    %       Kms     First   Second
*                          score  ival  radars  mobile  length  region  region
 set sam barrier CFCK      0.15   100   50      50      200     NKorea  SKorea
```

where CFCK is the Combined Forces Command, Korea. The fields "survival" and "% mobile" are not currently used; they have been included to facilitate future modeling of SEAD efforts. An area defense is specified in a similar format:

```
*                          Kill   Surv  # of    %       Kms
*                          score  ival  radars  mobile  area  region
 set sam  area CFCK        0.15   100   25      50      -     SKorea
```

The "–" in "kms area" means that the entire region is covered. Finally, a point defense can be specified by

```
*                          Kill   Surv  # of    %       Kms
*                          score  ival  radars  mobile  area  Airbase/target
 set sam  point CFCK       0.15   100   2       0       300   Osan
```

Parameter Inputs. A large number of parameters are used by ITM to adjudicate combat in theaters. Many of them have established default values that are our best estimates; however, in some cases, users are advised to enter values other than the default. The file korea.param will contain our current recommendations for parameter values other than the default. For example:

```
set itm DPRK  gnd_timing  25%  25%  10%  5%  10%  25%
set cmdgov SKorea  cntr_batt  0.5
set landwar CFCK cntr_batt_wgt  0.3
set landwar CFCK tng_min  0.5
```

These and other parameters are described in more detail in the parameter documentation file Force-C/A/Doc/parameter.doc.

Plan Directory Files

In contrast to the environment files, the Plan directory files are intended to lay out the character of the operating plans on each side. There is usually a separate C-Day (deployment day) file for each participant and a single D-Day (war initiation day) file, as well as other files, as required, to manage deployments and force operations. The following file descriptions refer to the Democratic People's Republic of Korea (DPRK; North Korea).

Deployment Instructions. The deployment files begin by orienting and echeloning commands using instructions such as

```
set command orient    KN2C  (50)axis.3W(Ndmz.3W)
set command orient    KS1C  -(40)axis.3W(Sdmz.3W)
order DPRK echelon    KN4E       KN2C   Uijongbu
order DPRK echelon    KN3        KN4E   Kuri/30/Yongin
```

Commands are oriented in ITM to locate them on the network and allow the analyst to understand the part of the network they will affect and attempt to control. However, defensive, positional commands (discussed below) are not oriented; instead, their location is defined by the location of their component forces. ITM will commit the units of echeloned commands in combat, as required; thus, echeloning is a convenient way to apply more mass in a sector for sequential employment, as required. After orientations have been entered (and assuming the presence of no positional commands), the battlefield can be pictured as shown in Figure 4.13. In this figure, echeloned commands are shown in a listing as in the case on KN2C on the left side of the figure, with its second and third echelon simply listed on top of the first echelon command.

A C-Day file will include instructions such as

```
order NKorea    assign      2-corps    KN2C
order NKorea    mobilize    troops     -       -      100%
order NKorea    control     DPRK
order DPRK      deploy      troops     -    NKorea  -     100%    -   -
```

These orders assign ground combat units to specific commands, turn over the control of North Korean units to the DPRK command, mobilize the ground forces, and deploy them to their default destinations (usually into their commands). In addition, where alliances exist, permission must be given for transiting national territory and for basing forces; these activities can be done using orders such as

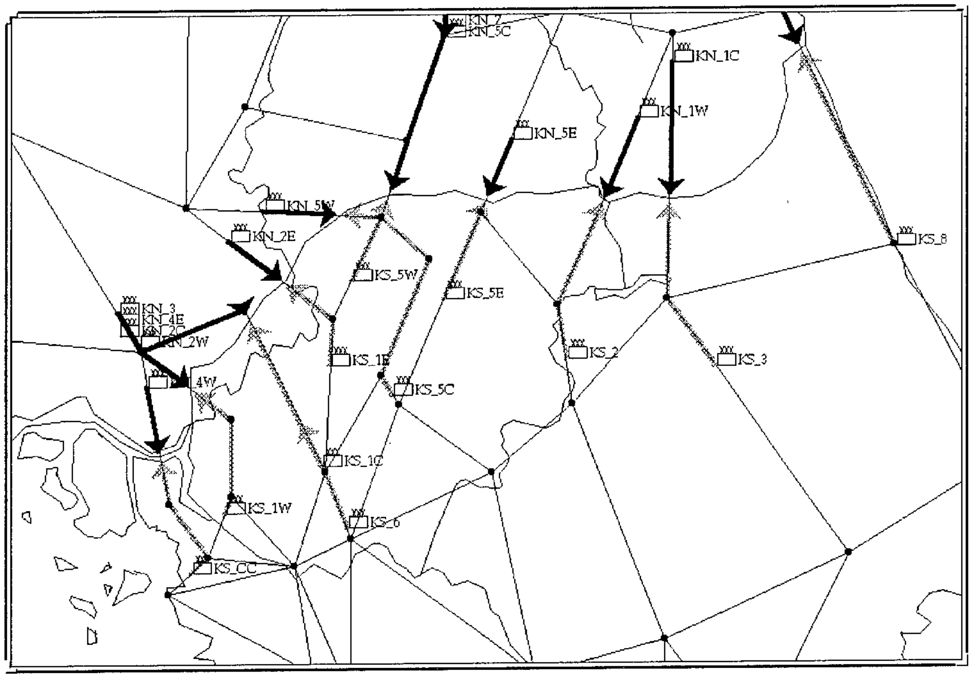

Figure 4.13—Oriented Commands

```
order SKorea    attitude   ally   us    end
order SKorea    permit     ally   all
```

Some ground forces are not very mobile and will be assigned to defend a particular piece of terrain rather than defending an entire path in depth; we refer to such units as *positional forces*. Forces can be given a positional mission by an order such as

```
order KS1C  gnd  posit  1-CORPS/25-ID  SKorea  -(20)axis.3W(Sdmz.3W)
```

With this order, the KS1C command instructs one of its subordinate units, the South Korean 1-CORPS/25-ID, to defend with its front on the south side of the DMZ along path axis.3W, to a depth of 20 kilometers. If there are preexisting defensive positions for such a force, they can be established with an order such as

```
set land KS1C   bld_bar   fortified  -(4)axis.3W(Kuhwa/14/Uijongbu)  set
```

This command builds a 4-kilometer-deep fortified defense along axis.3W starting at location Kuhwa/14/Uijongbu; the "set" says that the barrier is preexisting and does not need to be built.

Note that many other instructions could be entered to establish the parameters for either strategic movements or movements within the theater. For example, modifying the time required to alert a specific unit to be 24 hours can be done with an order of the format:

```
set unit alert_hours     1-CORPS/1-ID     SKorea      24
```

The deployment file ends by establishing the *log levels* for selected commands, the levels at which more details will be added to the model output, using an instruction such as

```
set command log-level KN2C 3
```

where a value of 0 discontinues detailed logging; a value of 1 causes ITM to report information such as major command posture changes by the LOC Commander; a value of 2 causes ITM to report information such as LOC Commander management of front and reserve forces; and a value of 3 causes ITM to report information such as effects of air strikes by individual squadrons. Log levels can also be set for individual ground forces. Users are cautioned to set the log level for most commands and units to 0 in order to avoid being inundated with log messages.

Combat Instructions. On D-Day, orders are entered that initiate combat. At that time, command missions are given of the format:

```
order KN2C    cmdmission    main-attack    axis.3W(Kuri/10/Yongin)    5  -  -
```

This order designates KN2C as a main attack (other alternatives include "spt-attack" and "pin-attack") along axis.3W with the objective of reaching the location Kuri/10/Yongin, allowing up to five divisions to operate on the front, and posing no attrition or time-stopping constraints (this order is described in more detail in file Force-C/A/Doc/orders.doc). A command can also be instructed to follow a first-echelon command and completely replace it when necessary (a full echelon's passing, as opposed to the gradual commitment of the second echelon) using the "follow" mission:

```
order KN8       cmdmission       follow       KN5C@60    5   -   -
```

where "@" signifies kilometers (60 here) behind KN5C.

Defensive command missions can be entered in the format

```
order KS1C    cmdmission    defend-withdraw   -axis.3W(Sdmz.3W)   5   -  -
```

which would have the defensive force fight in prepared positions and then withdraw when between such positions. Alternatively, a positional defense can be specified by an instruction such as

```
order KS1C   cmdmission   positional   -axis.3W
```

Positional commands require that all assigned forces be given positional missions, including artillery and armored units (note, however, that positional missions for forces can include a withdrawal rate, as appropriate).

Attack helicopter units may be employed in combat in several ways. If an attack helicopter unit is part of an oriented or positional command, its helicopters will fly in support of that command unless explicit orders direct otherwise. If not, the unit's assets can only be committed to support a forward command, using explicit orders such as

```
order CFCK   gnd    hel-support   17-AB   US    KSCC    32
order CFCK   gnd    hel-strike    17-AB   US    KN815   150
set helos    CFCK   flot_dist     50
```

The first order here commits 32 attack-helicopter sorties per day from the 17-AB to supporting command KSCC; the second order instructs the 17-AB to commit 150 sorties against the enemy command KN815 over whatever period of time is required to generate those sorties. Strikes take precedence over support. The parameter-setting order tells the helicopters under command CFCK that they can attack targets up to 50 kilometers in front of the command they are supporting, along its designated path. This setting applies to helicopters that are part of any command subordinate to CFCK.

Long-range artillery (e.g., ATACMS) is modeled in a manner similar to that for attack helicopters, employing either a support or a strike order:

```
order CFCK   gnd   arty-support   2-ID     US   KS1C    5    AT-ARM
order CFCK   gnd   arty-strike    214-FAB  US   KN815   20   AT-ARM
```

The first order commits 5 AT-ARM volleys per day from the 2-ID to supporting command KS1C; the second order instructs the 214-FAB to commit 20 AT-ARM volleys against the enemy command KN815 over whatever period of time is required to generate those volleys.

ITM allows the user to establish control plans or use files that will be executed when certain events occur. To designate such an event, enter an instruction such as

```
set command  call-plan  KN2C  Plan/evaluate_KN2C  CONL  Uijongbu
```

This tells ITM to invoke the file Plan/evaluate_KN2C when the CONL of command KN2C reaches Uijongbu.

Two kinds of history information are stored for ground combat. The traditional history files used by the JICM Graph Tool are initiated by the instruction

```
set force   itm-history   FEast     CFCK     DPRK        \
                          KSCC      KN4W     SKorea      \
                          KS1W      KN2W     SKorea      \
                          .
                          .
                          .
                          KS8       KN1E     SKorea   end \
                          ROKAF     7USAF    ...       end
```

where the first line defines the history setting used by Graph Tool (FEast) and the two theater commands, the subsequent lines define paired sets of commands that will oppose each other (up to ten sets of commands total), and the last line defines the air force commands for which history is to be maintained.

The other kind of history information (see Figures 4.23 and 5.15) is used in the "hist-gnd" and "hist-air" displays and is initialized by typing an instruction of the form

```
set force  his_init  CFCK  DPRK  KS1C  KN2C  ...  NKAF  ROKAF  end
```

where the user enters all commands for which the hist-gnd (or hist-air) display are to be issued.

Once all the background is completed, an attack is started by an order such as

```
order DPRK attack CFCK
```

At this point, the user may also wish to synchronize the model clock to D-Day using the instruction

```
set force day KD+0
```

Users are encouraged to review the files beginning with "korea" in the JICM Run/Plan directory, because they provide examples of the files required to run ITM through D-Day and somewhat beyond. Also, the JLASS 93 scenario files are included in the JICM under directories Run/Jlgrnd and Run/Jlair, and can be invoked using files Run/adv01, Run/adv02, Run/adv03, Run/adv04, and Run/adv05.

Ground Combat Outputs

ITM outputs come in two types: (1) on-line displays and graphics, and (2) CAMPAIGN output files. The new JICM Map graphics are documented separately, as are the JICM displays, and the history graphics are a variant of the former CAMPAIGN-ALT history graphics. The principal ground force displays are listed in Table 4.3 (the display interface names are shown in parentheses). Many of these displays have a simple variant and a detailed variant; the detailed variant is invoked by requesting the display with the first letter capitalized (see Table 4.3). Several of these displays are new with ITM and are illustrated here.

The new Units display with the *U* capitalized replaces the tg display of CAMPAIGN-MT. It provides the user with information on the specific network location of all the forces within a command. It is of the form shown in Figure 4.14.

The find display, illustrated in Figure 4.3, has an enhanced format compared with the format available in RSAS 4.6 and before.

The weapons and itm-ground displays show the count of weapons, EDs, or EEDs for the ground units of a government and of a command, respectively. For example, "display itm-ground KS5C weapons front" might yield the illustration in Figure 4.15.

The POMCUS display shows all prepositioned equipment sets worldwide. For example, it would show the information in Figure 4.16.

Table 4.3

ITM Ground Force Displays

Tabular displays:
Forces (Units, find, cmd, weapons, pomcus, itm-ground)
Weapons (resupply)
Deployments (path, loc, mobility, enroute, terrain)
Ground combat (Itm-land, itm-arty, Itm-helo, itm-barrier, Hist-gnd, battle)

```
Orig Curr
 EDs Pct   Name of Unit [Owner] Position (comments)
---- ---- -------------------------------------------------------
--
0.30  60% 5-CORPS/6-ID [SKorea] Chorwon
0.50 100% 5-Corps/8-ID [SKorea] Kalmal/8.0Kms/Pochon
0.20 100% 5-CORPS/1-ARMB [SKorea] Chorwon/7.0Kms/Kalmal (moving)
```

Figure 4.14—The Units Display

ITM Total Weapons display for KS_5C as of Day10,1200Z											
	Tank	IFV	APC	Hvy ARV	Lgt ARV	LR ATGM	SR ATGM	Sm Mort	Sm Arms	SP Arty	TD Arty
5-CORPS/6-ID[SKorea]	30	10	0	0	12	10	300	150	5000	0	80
5-CORPS/1-ARMB[SKorea]	100	50	50	0	30	20	80	20	500	30	0
Command Total											
	Tank	IFV	APC	Hvy ARV	Lgt ARV	LR ATGM	SR ATGM	Sm Mort	Sm Arms	SP Arty	TD Arty
	130	60	50	0	42	30	380	170	5500	30	80

Figure 4.15—The Weapons Display

POMCUS Set names, locations, and affiliations are:		
1Mech2BdeSets	FrankfurtMain	Unaffiliated
3Arm2BdeSets	FrankfurtMain	Unaffiliated
4Mech2BdeSets	FrankfurtMain	Unaffiliated
3ACR1RegtSet	FrankfurtMain	Unaffiliated
USMCSet	TromsoBardufoss	Unaffiliated
MPS Set names, task-groups, and affiliations are:		
UKMebSet	MPS.SQDN.1	Unaffiliated
DiegoMebSet	MPS.SQDN.2	Unaffiliated
GuamMebSet	MPS.SQDN.3	Unaffiliated
ArmyHvyBde	MPS.SQDN.4	Unaffiliated

Figure 4.16—The POMCUS Display

The path display gives the land and sea routes from one location in the network to another location, and notes distances that must be traveled by a path other than land. For example, the request "Display path Washington US Pusan -" would yield Figure 4.17. Note that the path goes to Savannah because Savannah is the default port for the region in which Washington is located. The user could easily go directly from Norfolk to Pusan, for example, by so stating the path.

The terrain display shows the nature of the terrain along a single link in the JICM network. For example, a request of the form, "display terrain Uijongbu Seoul" would show Figure 4.18.

The ITM-land display defines the current status of a ground force command. A request of the form "display Itm-land KS5C" would yield Figure 4.19.

The ITM-arty display shows the fire plan for long-range artillery. A request of the form "display itm-arty cfck yes" yields a display like that in Figure 4.20.

```
Routing and distances are:
                          Dist       Cum
             Place       (Kms)      Dist
  ---------------- -------  -------
        Washington       0      START
           Norfolk   262.1      262.1
           Lejeune   269.7      531.8
        Charleston   364.7      896.5
          Savannah   149.0     1045.5  Land Leg    1045.5
    -----------------------------
         WAtlantic  3104.0     4149.5
         SAtlantic  3369.0     7518.5
       HornPassage  6348.0    13866.5
        ESEPacific   231.0    14097.5
             Pusan 16231.0    30328.5   Sea Leg   29283.0
    -----------------------------
    1045.5 Total Land Kms
```

Figure 4.17—The Path Display

```
The terrain FROM Seoul TO Uijongbu is as follows:

   13.8 Kms of  12.0Km-wide Urban terrain
           FROM Seoul TO Seoul/13.8Kms/Uijongbu
   14.4 Kms of  12.0Km-wide Mixed terrain
           FROM Seoul/13.8Kms/Uijongbu TO Uijongbu
```

Figure 4.18—The Terrain Display

The ITM-helo display shows the planning for attack helicopters. A request of the form "display itm-helo cfck no" yields a display like that in Figure 4.21.

The ITM-barrier display shows where defensive positions have been prepared along a particular path. An instruction of the form "display itm-barrier axis.4" yields a display like that in Figure 4.22.

The hist-gnd display provides historical information on the status of ground combat weapons in a particular command, as shown in Figure 4.23. It is invoked by an instruction of the form "display hist-gnd KS_5C." The extended version of this display (obtained by requesting "Hist-gnd" with a capital *H*) adds information on the cause of the losses of the ground equipment.

Known Limitations

With any model, there are trade-offs in determining what capabilities to add. As we have developed ITM, we have generally tried to complete the basic ITM

```
ITM Land Combat Display for KS_5C at Day7,1200Z
  Its positional orientation is 60.0Kms long between:
      MOFL/CONL is at Chorwon
      CBTZ is at Kalmal/10.4Kms/Sinpal
  Its mission is Positional along the following path:
    >Pusan>JctSKor1>Kyongju>Yongchon>Taegu>Taejon>Chongju>Yoju
    >Chongpyong>Sinpal>Pochon>Kalmal>Chorwon>Pyonggang>Sepo>Wonsan
  Its positional forces now in position are:
    5-CORPS/6-ID[SKorea]:  0.300Ed  0.250EED  60%Str  60%Coh
      Its ITM mission is Positional along the following path:
      >Kalmal>Chorwon
      Its front is at Chorwon
      Its rear is at Kalmal/1.0Kms/Chorwon
      Its current enemy contacts are:
        KN_5C's front contacts 5-CORPS/6-ID's front at Chorwon
    5-CORPS/8-ID{SKorea]:  0.500Ed  0.495EED  100%Str  100%Coh
      .
      .
      .
  Its other assigned forces are:
    5-CORPS/50-ID[SKorea]:  0.400Ed  0.300EED  100%Str  100%Coh
    It is at Yoju en route to Pochon by sfc
    Its ITM mission is Positional along the following path:
    >Chongpyong>Sinpal>Pochon
  TOTAL for Command:              EDs    EEDs
    Mobile in Command area      0.000  0.000
      At Front:                 0.000  0.000
      Reserve:                  0.000  0.000
      Flanks:                   0.000  0.000
      Security:                 0.000  0.000
      Reconstitute:             0.000  0.000
      Other:                    0.000  0.000
    Positional in position:     1.200  1.100
    Other assign forces:        0.400  0.300
    Total:                      1.600  1.400
```

NOTE: "sfc" is the abbreviation for *surface*.

Figure 4.19—The ITM-land Display

design done 18 months ago and to add issues that appeared important as we progressed. For various reasons, we have deferred some parts of the original design, such as SOF modeling (which we deferred to pursue JICM documentation, but will return to if future JICM development is funded). A more complete list of issues for which further development is planned is included in the next subsection.

```
ITM Long Range Artillery Display for CFCK as of Day7,1200Z
  ATACMS Assigned: 3.0  Ready: 3.0  Volley/Wpn/Day: 4
    Load-1: 2 AT-ARM (score 5.00) ammo for 100 volleys O/H
    Load-2: 2 AT-INF (score 2.00) ammo for 500 volleys O/H
  Period Timing is: 0% 40% 30% 30% 0% 0%
  Tasking Status for day 7 thru period ending Day7,1200Z
  2-MXD ATACMS/AT-INF volleys striking KN-2C
    Planned: 5  Shot: 2  Canceled: 0  Score: 2.000
```

Figure 4.20—The ITM-arty Display

```
ITM Attack Helicopter Display for CFCK as of Day7,1200Z
  Assigned: 30.0  Ready: 30.0  SortRate: 4  AvgScore: 1.000
  Period Timing is: 0% 0% 40% 30% 30% 0%
  Current support and strike missions:
    2-MXD supports KS_1C with 30 sorties/day
  Tasking Status for day 7 thru period ending Day7,1200Z
    2-MXD support for KS_1C (sorties today):
      Planned: 30  Flown: 12  Canceled: 0  AvgScore: 0.800
```

Figure 4.21—The ITM-helo Display

```
KS_5C has 4.0 Kms of Prepared positions:
  They start at Chorwon
  They run through Chorwon/4.0Kms/Kalmal
  They are ordered thru Chorwon/4.0Kms/Kalmal
```

Figure 4.22—The ITM-barrier Display

Because ITM is a theater-level model, it is not appropriate for examining tactical detail, including issues such as basic weapon capabilities (for example, evaluating the upgrade of units having M-113 armored personnel carriers to an M-2/M-3 configuration). However, such issues should not be decided purely on tactical merit; rather, they should be evaluated in the context of their effects on operational and strategic outcomes. The only procedure for doing so is to evaluate these trade-offs with a detailed model, then represent the trade-offs in more-aggregate terms in a model such as ITM to derive strategic and/or operational consequences.[12] This is a limitation only in the sense that ITM (or any other model we are familiar with) is unable to answer all questions by itself and, therefore, in some analytic efforts, must be used in conjunction with other, more-detailed models.

[12]Some analysts currently are hopeful that highly detailed models will someday be able to simply do operational-level analysis as computers become faster; however, as argued in Section 2, such an approach ignores the operational and tactical discontinuities that current military science is unable to resolve.

Ground History for KS_5C between Day5,0000Z and Day7,1200Z

Type of Weapon ED	Day5 --- Surviving		Day 5 <---------------> M+F+K-Killed		Fixed/Issued		Day7 --- Assigned		Day7 Surviving	
Tank	200	0.200	20	0.020	5	0.005	0	0.000	185	0.185
IFV	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
APC	100	0.020	10	0.002	0	0.000	20	0.004	110	0.022
Hvy_ARV	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
Lgt_ARV	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
Lr_ATGM	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
Sr_ATGM	1000	0.100	100	0.010	20	0.002	0	0.000	920	0.092
SM_Mortar	500	0.100	50	0.010	10	0.002	0	0.000	460	0.092
Sm_Arms	20000	1.000	2000	0.100	400	0.020	0	0.000	18400	0.920
SP_Arty	100	0.050	10	0.005	2	0.001	0	0.000	92	0.046
Td_Arty	500	0.200	50	0.020	5	0.002	0	0.000	455	0.182
		-----		-----		-----		-----		-----
TOTAL EDs		1.670		0.167		0.032		0.004		1.539
		-----		-----		-----		-----		-----
Gded_ADef	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
OIR_ADef	50	0.010	10	0.002	0	0.000	0	0.000	40	0.008
Atk_Helo	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Other_1	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
Other_2	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000

Figure 4.23—The hist-gnd Display

A final, important limitation reflects the emphasis to date on developing a model for analytic war gaming. Because of this analytic war gaming approach, a number of major discontinuities in outcomes are a natural part of the model (for example, breakthroughs either happen or they do not); as a result, a combination of these discontinuities can lead to results that, on the surface, seem inconsistent. Thus, an improvement in some input factor may lead to a poorer outcome for that side; but upon closer inspection, it may even seem reasonable that such a result occurs. For example, whereas adding divisions to a defense might make that defense tenable, it might also cause the defender to hold an untenable line a bit longer, with the result that the subsequent breakthrough and encirclement destroy much larger forces than would have been lost had the line been abandoned early on. This kind of behavior will be unacceptable to many resource analysts who expect outcomes to be monotonic with the quantity of resources applied. Monotonicity is usually gained in such an analysis by artificially forcing the same decisions to be made with differing force levels; for example, having a command withdraw at the same time in a battle regardless of its force level. Alternatively, sophisticated optimization models can often gain monotonicity in such conditions (although there is no guarantee, given stochastic events such as breakthroughs); CAMPAIGN-MT and its supporting war plans

currently lack such a rigorous strategy-selection methodology (although one could be developed), following a more incremental approach to operations.

Users are encouraged to discuss any specific application with Bruce Bennett, Carl Jones, or Barry Wilson of RAND, to identify problem areas to avoid or to determine appropriate adjustments.

Plans for Enhancement

This is the first operational version of JICM-ITM. We are eager for feedback on development priorities. We had originally proposed to work in three areas in FY93 (air superiority and defense, advanced land combat, and littoral control and projection), but we changed our plans to a focus on documentation after JICM 1.0 was completed. We have proposed a return to these three areas if further JICM development is funded.

Some specific areas in which RAND has not yet completed the original ITM ground combat design or in which we recognize further work would be appropriate include the following:

- Resolve the difficulty in reflecting how flank attacks might split the opposing command that is attacked in the flank.
- Complete the modeling of air assaults and airborne insertions.
- Model the penetration into the enemy rear of forces such as operational maneuver groups, and show the effect that they might have. Included would be an enhanced representation of rear-area battles that would apply to this case, to successful flank attacks, to airborne or air assault operations, to amphibious landings, and to positional forces that are overrun.
- Model SOF operations in the aggregate, according to the original ITM design, which would include representation of insertions, direct action and special reconnaissance missions, and rear-area security and/or counter-SOF operations.
- Add a killer-victim scoreboard methodology for combat adjudication in addition to the basic Situational Force Scoring methodology. Such a methodology has been devised by another RAND project, which is developing appropriate data for the methodology as this section is being written; it should be ready for introduction if future JICM development is funded.

- Add a representation of combined-arms effects that goes beyond Situational Force Scoring and captures such issues as the mobility and protection of the forces.
- Allow for the definition of support vehicles and the effects that they have on combat.
- More realistically assess major river crossings and other actions through difficult terrain.
- Model the consumption of POL.
- Provide for integration of RAND's new TLC/NLC (theater-level combat/nonlinear combat) theater-level model within the JICM framework at some future time.

5. Air Operations in ITM

Daniel Fox

This section introduces the air model in the JICM Integrated Theater Model (ITM). The section begins with a general description of the air model, then presents detailed descriptions on how orders are used to affect the air war. The section goes on to discuss the execution of air sorties and the model parameters that can be adjusted to affect the air war outcomes.

ITM was created to take advantage of the best features of both the previous RSAS Main Theater (CAMPAIGN-MT) and Alternate Theater (CAMPAIGN-ALT) models. By incorporating features of both CAMPAIGN-MT and CAMPAIGN-ALT in a single model, the consistency and ease of use of the RSAS were enhanced.

Conceptually, the ITM air model consists of three modules. The first is a planning module that produces an air plan based on user inputs (planning guidance) and parameters. This plan, in the form of an air tasking order (ATO), is based on estimated available air-to-ground and air-to-air sorties. The second module simulates the execution of the air plan represented by the ATO, including adjustments to the air plan accounting for the actual sorties available. Finally, the third module adjudicates damage and attrition resulting from the execution of the plan.

Level of Detail

The ITM air model includes explicit planning and creates *packages* of aircraft—combining of aircraft assigned differing missions into a single flight or group to achieve the synergies of the separate missions—in the air planning vehicle, the ATO. Execution is implicit: Individual packages of aircraft are not simulated individually but are treated as levels of effort within 4-hour adjudication cycles. For example, within each 4-hour adjudication cycle, the level of effort of air defense on one side is pitted against the penetrating attacks of the other, and these efforts are treated as an aggregate whole rather than as a series of individual, timed engagements. Theater ground-to-air defense is treated in three components: barrier defenses between regions, area defenses within regions, and point defenses at targets.

Air planning guidance, provided by the JICM analyst, involves a series of decisions including *rerole* (determining the fraction of multirole aircraft used in air-to-ground, as opposed to air-to-air, missions), apportionment, and allocation. Air planning is centered around a number of mission types, most of which are recognized by the USAF (and published in *AF Manual 1-1*), although others are typically associated with countries steeped in Soviet air employment concepts. The air-to-ground missions are close air support (CAS), battlefield air interdiction (BAI), air interdiction (AI), offensive counter-air (OCA), suppression of enemy air defenses (SEAD), and quick-reaction alert (QRA). The air-to-air missions are defensive counter-air (DCA), cover, area defense, airfield defense, sweep, and attack. In addition, specialized missions of AWACS, JSTARS, and electronic countermeasures (ECM) are included. The following paragraphs briefly describe the critical characteristics of these air missions.

Close Air Support

Close air support is air-to-ground attack of enemy troops currently in contact with friendly ground forces. This is a specialized mission that, in the real world, has two forms: preplanned and on call. From the perspective of the friendly troops, CAS is essentially another form of indirect (e.g., artillery) fire. Actual employment generally depends on coordination with either ground or airborne forward air controllers (FACs) trained to communicate with pilots performing this mission. In ITM, CAS is targeted by specifying the ground command to be supported. If the specified command is not in contact at the time the CAS missions are flown, then CAS missions are automatically converted to BAI missions (see the next paragraph).

Battlefield Air Interdiction

Battlefield air interdiction is air-to-ground attack of enemy troops not currently in contact with friendly forces but generally within 72 hours of such contact. Because friendly ground units may also direct fire against the enemy forces, these missions are coordinated with friendly ground forces—for example, to prevent the embarrassment of having a flight of aircraft in the vicinity of an artillery bombardment target. Ground commanders also want coordination to handle fluid battlefield conditions when the ground combat situation changes rapidly or the front is very nonlinear. Various arrangements have been made between the U.S. Army and the U.S. Air Force about how far away targets must be before they are no longer considered to be BAI. Agreements often involve what is called the Fire Support Coordination Line (FSCL), which is sometimes defined in terms of

time and sometimes defined in terms of distance. Targets beyond the FSCL are not considered BAI targets, and air attack of those targets does not require coordination with the ground force commander. Interdiction targets closer to friendly forces than the FSCL are considered to be BAI targets requiring close coordination with the ground forces. In ITM, BAI (like CAS) is targeted by specifying the ground command to be supported. If the specified command has no BAI targets at the time of the BAI mission, then the BAI sorties are automatically converted to CAS missions. If a command has neither CAS nor BAI targets available, then the sorties are aborted (there is no ITM provision for reallocating these sorties to another command).

Air Interdiction

Air interdiction covers a variety of air-to-ground attacks against enemy troops, mobility, or infrastructure targets. It can include attacks on troop masses to the rear, logistics buildups or convoys, or C3 sites, on up to strategic targets, such as power generation or distribution capability.

Offensive Counter-Air

Offensive counter-air is air-to-ground attack of enemy airfields with the aim of limiting the ability of the enemy to generate air sorties. Targeting on the airfield may be against the runway, aircraft, maintenance facilities, fuel, or logistics supplies.

Suppression of Enemy Air Defenses

Suppression of enemy air defenses seeks to limit the effectiveness of enemy surface-to-air missiles (SAMs) and air-defense artillery (ADA). This mission has two components, one lethal and one nonlethal. The nonlethal component consists of *electronic countermeasures*, or jammers, which prevent the enemy search and tracking radars from identifying or locating incoming aircraft. The ECM component consists of both area jammers, such as the EF-111, which generally orbits on the friendly side of the FLOT using high power to blind enemy radars; and escort jammers, which represent jamming capability carried with the attack package of aircraft.

The lethal component is best represented by the F-4G Wild Weasel. With the phasing out of the F-4G from the U.S. inventory, one can anticipate enhancements to other aircraft, such as the F-15E, for the SEAD mission. Lethal

SEAD missions may be coordinated with attacking packages to create safe (relatively speaking) entry corridors into heavily defended bands such as the FLOT. Lethal SEAD may also be part of the escort associated with an attack package and would generally be used to suppress point defenses in the target area. The F-4G aircraft includes special radar and warning (RAW) gear not only to detect but to localize ground radar emitters. It also carries a high-speed anti-radiation missile (HARM) designed to home in on and attack those ground radar emitters. The high-speed aspect of the missile is important because the ground radars will switch off if they suspect that they are under attack. Modern versions of the HARM remember where the signal was coming from if the signal is lost and continue to press the attack (of course, the best accuracy is obtained if the enemy radar stays on to guide the missile right until impact). Note that lethal SEAD need not kill enemy radars in order to do its job: If the enemy radars are switched off because the radar operators fear attack, then suppression is accomplished. Without radar information, further guidance instructions to surface-to-air missiles cannot be given and the trajectories of these missiles becomes ballistic and not a serious threat to aircraft.

In ITM, lethal SEAD is both an explicit mission and an escort task. Aircraft assigned to the explicit SEAD mission will degrade the effectiveness of enemy ground-to-air barrier defenses. SEAD escort in attacking packages will improve the survivability of the package in all encounters with ground-to-air defenses.

ITM provides for both area and mission packaging of ECM; however, the effects are not yet incorporated into the simulation results.

Quick-Reaction Alert

Quick-reaction alert refers to tactical aircraft that have a nuclear mission. It typically involves a limited number of aircraft but is given a high priority. The ITM does not execute these QRA aircraft; it simply decreases the aircraft inventory available for conventional missions

Defensive Counter-Air

Defensive counter-air missions remain on the friendly side of the FLOT and attempt to disrupt and destroy enemy air attacks. In U.S. doctrine, the DCA mission represents one large pool that is called upon to defend against all kinds of attacks. Soviet procedures often involved *fencing assets* (i.e., the Soviets had specific subcategories that they used explicitly) for specific defensive missions, including point defense of a specific class of ground targets such as airfields

(called *airfield defense*), interdiction targets (called *area defense*), or defense of CAS and BAI mission aircraft in the air (called *cover*).

Attack

Attack is an offensive air-to-air mission that targets AWACS, JSTARS, or tanker targets. This is not an explicitly recognized USAF mission but would fall under the general category of counter-air operations. Such missions may not kill the target, but they do have the effect of consuming air defense resources and perhaps forcing the targeted aircraft to operate at a greater distance from the FLOT, where effectiveness is reduced. Sorties can be apportioned to this mission in JICM 1.0; however, the effects have not yet been incorporated into the simulation results.

Sweep

Fighter *sweeps* represent the projection of air-to-air assets over enemy territory. They are done in an attempt to engage and disrupt enemy attacks before such attacks can penetrate friendly airspace.

AWACS

The primary role of *AWACS* is to aid in coordinating the air-to-air aspects of air defense. This is a specialized mission that can be performed only by AWACS aircraft. In the ITM simulation, an airborne AWACS mission increases the likelihood that enemy aircraft will be engaged by defenders.

JSTARS

JSTARS is another specialized mission that can be performed only by JSTARS aircraft. The major advantage of JSTARS is its ability to track moving targets on the ground. In the ITM simulation, an airborne JSTARS mission increases the air-to-ground effectiveness of rear-area attacks on enemy ground units (BAI and AI).

Theater Definition

Surface-to-Air Missiles

Surface-to-air-missile defenses are divided into three categories: barrier, area, and point defenses.

Barrier SAMs defend the border between two regions and are encountered by packages crossing between those regions. They are defined by the following set command:

```
*                owner score surv #radar %mobile Kms rgn1   rgn2
set sam barrier DPRK  .15   100    30       50   200 SKorea NKorea
```

Area SAMs defend an entire region and are encountered by packages penetrating that region. They are defined by the following command:

```
*             owner score surv #radar %mobile Kms Region
set sam area DPRK  .15   100    50       0     -  NKorea
```

Point SAMs defend a specific airbase, port, or generic target class (such as PROD_ammo) and are encountered by OCA and AI packages attacking those targets. They are defined by the following command:

```
*              owner score surv #radar %mobile Kms Target
set sam point DPRK  .15   100     2       0    400 Pyongyang
```

The represented surface-to-air defenses may be displayed with the ITM-sam display. A sample output is illustrated in Figure 5.1.

Source, Destinations, and Routes Definition

Aircraft assigned to a command may not be able to participate in the air war. For example, continental U.S. (CONUS)-based tactical reinforcement aircraft,

```
Status of SAMS assigned or subordinate to CFCK as of Day0,0000Z
                  Type  Orig.  Surv.   Pct.    Area/
      Command SAM Def  Radar  Radar Mobile   Length Positioning
------------- ------- ------ ------ ------ -------- -----------
         CFCK   Point   10.0   10.0  50.0%      400 Inchon (Port)
         CFCK   Point    2.0    2.0   0.0%      800 Osan (AB)
         CFCK   Point    1.0    1.0   0.0%      400 Kunsan (AB)
         CFCK   Point    1.0    1.0   0.0%      400 Sachon (AB)
         CFCK   Point    4.0    4.0   0.0%      800 Kimhae (AB)
         CFCK   Point    2.0    2.0   0.0%      400 Pusan_AB (AB)
         CFCK   Point    2.0    2.0   0.0%      400 Taejon_AB (AB)
         CFCK   Point    1.0    1.0   0.0%      400 Pohang (AB)
         CFCK   Point    1.0    1.0   0.0%      400 Chongju (AB)
        7USAF    Area    2.0    2.0 100.0%   654141 JapanSea
        7USAF    Area    3.0    3.0   0.0%    12075 Guam
         CFCK    Area   25.0   25.0   0.0%    99598 SKorea
         CFCK Barrier   25.0   25.0  50.0%      200 NKorea/SKorea
```

Figure 5.1—ITM-sam Display

although assigned in the JICM data base to CFCK, cannot fly missions until deployed to the theater of operations. In other cases, political constraints, for example, refusal of Japan to permit offensive missions into Korea from bases in Japan, must be represented. The permissions must be specifically provided through instructions that make foreign governments allies and then grant permissions to those allies:

```
order SKorea attitude ally US UK Australia end
order SKorea permission ally airops end
```

The "airops" permission includes all lesser permissions, such as basing and overflight, and thus facilitates all required actions.

For each command, a list of regions from which combat missions may be flown is specified. Thus, aircraft assigned to a command but located in a region from which combat missions are not permitted will not be incorporated into the ATO. The allowed regions are specified by identifying the command and a list of regions, as follows:

```
set airwar NKAF        fly-from  NKorea  end
set airwar ROKAF       fly-from  SKorea  end
set airwar 7USAF       fly-from  SKorea Japan Okinawa Guam end
set airwar KUSNAV-AIR  fly-from  YellowSea end
set airwar KUSMC-AIR   fly-from  SKorea  end
```

Likewise, the regions in which targets may be attacked are specified with a similiar set of instructions. Orders to attack targets outside those regions will be ignored. Note that friendly regions must be listed so that enemy forces that may have advanced into those regions can be attacked:

```
set airwar NKAF        tgt-into  SKorea NKorea  end
set airwar ROKAF       tgt-into  NKorea SKorea  end
set airwar 7USAF       tgt-into  NKorea SKorea  end
set airwar KUSNAV-AIR  tgt-into  NKorea SKorea  end
set airwar KUSMC-AIR   tgt-into  NKorea SKorea  end
```

To define the air defenses encountered by attacking air packages, information about potential penetration routes must be specified. Since ITM does not use explicit routes, specification is done by entering the percentage of missions penetrating various regions and the percentage of the air defense that missions will encounter. For example, suppose missions from 7USAF attack into NKorea and that 20 percent of the missions will fly through the region YellowSea, 20 percent will fly through the region JapanSea, and 100 percent will fly through the region NKorea. In NKorea these flights potentially encounter 90 percent of the barrier and area SAM defenses and 70 percent of the North Korean interceptors. In addition, these flights encounter 20 percent of the interceptors allocated to the

YellowSea and JapanSea, if any, as illustrated in the example below. Every allowable target region (set in tgt_into above) should be included here.

```
*                                  Target Enroute     SAM      INT    Flight
*                                  Region Region(s) percent  percent  percent
set airwar 7USAF    pen-route    NKorea NKorea      90%      70%     100%   \
                                 NKorea YellowS      0%      20%      20%   \
                                 NKorea JapanS       0%      20%      20%   \
                                 SKorea SKorea       0%       0%     100%   end
set airwar NKAF     pen-route    SKorea SKorea      90%      80%     100%   \
                                 NKorea NKorea       0%       0%     100%   end
set airwar ROKAF    pen-route    NKorea NKorea      50%      20%     100%   \
                                 SKorea SKorea       0%       0%     100%   end
```

Preparation of Forces

Preparing air forces to participate in combat includes alerting, assigning, and deploying those forces. Since none of these steps has changed from the RSAS, only short examples of these steps will be included here.

Air forces are alerted with the Alert order. The force to be alerted can be either a specific named unit or can be a JICM force type:

```
order US   alert 33-TFW/56-TFS 100%
order NKor alert air           100%
```

Air forces must be assigned (with the Assign order) to a theater command participating in the combat or to an air command subordinate to that theater command:

```
order US   assign 33-TFW  7USAF
order NKOR assign tacair  DPRK
```

The government owning the forces must yield operational control (with a Control order) to a command before the command can issue orders to the forces:

```
order US     control CFCK
order SKorea control CFCK
order NKorea control DPRK
```

Finally, air forces must be located in regions from which combat missions are permitted. To do so often requires deployment of the forces. The command to which forces have been assigned or any superior command may issue orders to those forces. Thus CFCK, a superior command to 7USAF, can order the deployment of forces assigned to 7USAF (with a Deploy order):

```
order CFCK deploy 33-TFW/56-TFS US Osan
```

After preparing forces, the cmd air display may be used to summarize the air assets available to any command. In requesting this display, it is possible to specify a command, an owner, and a region in order to closely identify which forces to display. A sample cmd air display (produced by "display cmd air CFCK - -") is shown below in Figure 5.2.

ATO Creation Guidance

Rerole

The first major input into the ATO is the decision on how to employ the multirole assets. It is done by specifying for each command the percentage of multirole aircraft to be "roled" for air-to-ground missions, or *reroled*:

```
set airwar CFCK  multi_ag 60%
set airwar 7USAF multi_ag 60%
set airwar DPRK  multi_ag 0%
```

The current percentage of assets roled for air-to-ground is included in the itm-air display, a portion of which is shown in Figure 5.3. The percentage of assets roled for air-to-ground is labeled "MultGnd" under other apportionments.

```
Assigned CFCK, Owned by Anyone, Located Anywhere (00:00 GMT, day 1,
case a98)

                              Surviving Aircraft      Need    F-16A
Equivlnts
Units Type      Specialty   A-A   A-G  Mult  Othr     Mob    Air-Air   BAI
----- --------  ---------  ----- ----- ----- -----   -----   -------  -----
    1 A-37      CAS                   22                                  1
    2 F-15      Fighter       36                                   80
    1 F-15E     Multi                       18                     40    13
    3 F-4       Multi                       53                     16    10
    6 F-4       Fighter      111                                   33    11
    2 A-16      Multi                       48                     43    33
    9 F-16C     Multi                      176             24     195    84
    2 F-16C     Fighter       36                                   12     5
    1 F-117     Interdic              18                                 10
    1 Basw-hx   ASW                               24
    2 S-2       ASW                               30
    1 P-3       ASW                               13
    2 KC-135    Tanker                            18
    1 ANG-Tnk   Tanker                            10
    1 EF-111a   ECM                               10
    1 E-3       AWACS                              3
    7 F-5       Multi                      117                     30    17
----- --------             ----- ----- ----- -----   -----   -------  -----
   43 Total                  183    40   412   108      24     449    184
      Total Aircraft =   743
```

Figure 5.2—Output for cmd air Display

Air Orders for CFCK as of Day1,0000Z				
Other Apports:	ECMArea	AWACS	JSTARS	MultGnd
	90%	90%	90%	50%

Figure 5.3—Percentage of Multirole Aircraft for Air-to-Ground

Apportionment

The weight of effort for the various missions (*apportionment*) is specified separately for the air-to-ground and the air-to-air missions. Air-to-ground missions apportioned (with the Apportion order) to QRA and air-to-air missions apportioned to withhold (Hld) missions will not participate in combat.

```
*                                CAS BAI AI OCA SEAD QRA
order 7USAF apport  air-gnd      20  35 10  35  0    0
*                                DCA Cvr ArDef AfDef Swp Atk Hld
order 7USAF apport  air-air      70  0    0     30   0   0   0
```

The current apportionments, by command, are included in the itm-air display as illustrated in Figure 5.4.

Allocation

Allocation identifies where the effort apportioned to a specific mission is to be applied. Allocation orders are required for CAS, BAI, AI, and OCA air-to-ground missions. For the air-to-air missions, defensive counter-air (DCA) and airfield defense (AfldDef) missions require allocation orders. For each mission the allocation is slightly different. The various allocation orders are described below.

Both CAS and BAI are allocated by percentages to the supported ground commands. If close combat on the ground has not yet begun, then CAS missions are automatically converted to BAI sorties for the same command. Similarly, if no BAI targets are available, then BAI sorties are converted to CAS. If neither

Air Orders for 7USAF as of Day 1,0000Z							
Air-Gnd Apports:	CAS	BAI	AI	OCA	SEAD	QRA	
	20%	35%	10%	35%	0%	0%	
Air-Air Apports:	DCA	COVER	AREA	AFLD	SWEEP	ATTK	W/H
	70%	0%	0%	30%	0%	0%	0%

Figure 5.4—itm-air Display of Apportionments

CAS nor BAI sorties can be employed for the specified command, then the sorties are wasted (there is no provision to divert sorties to another command). The CAS and BAI allocation specifies the friendly ground command or commands to be supported and the percentage of the CAS or BAI effort to be used to support each command. The Allocate orders below call for a 50/50 split of both the CAS and BAI effort to the ground commands KS1C and KS5C.

```
order 7USAF alloc CAS  KS1C 50  KS5C 50% end
order 7USAF alloc BAI  KS1C 50  KS5C 50% end
```

Allocation of the AI effort identifies target types to be struck and the percentage of the AI effort to expend on each target. The targets can be enemy units, lines of communication (LOCs), or infrastructure targets represented in the JICM data base. The percentages for all targets must, of course, sum to 100.

Enemy units are specified by name and owner. From an intelligence perspective it is assumed that when the JICM analyst specifies a ground unit to be attacked, there is sufficient intelligence information to target that unit. The model uses the name of the unit for targeting purposes, but there is no requirement that the unit name be known in any real-world sense in order to initiate an air attack. To initiate air attacks, only certain minimal real-world location information is actually required. The AI allocation order to attack, for example, the 10th and 11th infantry divisions (IDs) of the North Korean 1st Corps, with three-fourths of the effort against the 10th ID, would be

```
order 7USAF alloc AI  1-CORPS/10-ID[NKorea] 75% \
                      1-CORPS/11-ID[NKorea] 25% end
```

Specifying a line of communication as an AI target means that an ITM link will be attacked, delaying units and supplies moving on the link. To specify the link, the names of the places that the link connects must be given, along with the percentage of the AI effort to use against that LOC. For example, to attack with equal efforts the link that connects Sohung and Kaesong and the link that connects Sibyon and Yonchon, the following allocation order could be used:

```
order 7USAF alloc AI  THTR_loc/Sohung/Kaesong 50% \
                      THTR_loc/Sibyon/Yonchon 50% end
```

Other infrastructure targets, except ports, are identified by specifying the region in which the targets are located and the owner of those targets, along with the percentage of the AI effort to use against them. Ports are targeted by JICM place. For example,

```
order 7USAF alloc  AI  STOR_nucwpn/NKorea/NKorea 50% \
                       STOR_chem/NKorea/NKorea   25% \
                       PORT_lift/Nampo           25%  end
```

If desired, any or all of the above target types could be combined into an AI allocation if AI is to be simultaneously used against multiple target types. For example, the following AI allocation could be used:

```
order 7USAF alloc AI  1-CORPS/10-ID[NKorea]      15% \
                      1-CORPS/11-ID[NKorea]       5% \
                      THTR_loc/Sohung/Kaesong    25% \
                      THTR_loc/Sibyon/Yonchon    10% \
                      STOR_nucwpn/NKorea/NKorea  15% \
                      STOR_chem/NKorea/NKorea    15% \
                      PORT_lift/Nampo            15% end
```

Allocation of OCA specifies a list of airbases to be attacked in priority order. If no allocation is given, then all airbases in the target regions (specified by AIRWAR->tgt_into) are ranked according to the maximum air-to-ground score of the aircraft on the base. Alternatively, airbases may be ranked according to the air-to-air score of aircraft by setting the parameter AIRWAR->oca_priority to off. If an allocation is given, it overrides either default priority list. The level of effort against each base on the priority list is one OCA package. That is, on each day one OCA package will attack each base until the base is damaged to a level below the setting of the parameter AIRWAR->oca_dam_crit (default 50%). Any base so damaged will be moved to the bottom of the priority list. If the OCA apportionment produces more OCA packages than there are bases on the priority list, then after one package is assigned to each base on the list, the bases are assigned an additional package, again based on priority. A sample OCA allocation is

```
order DPRK alloc OCA Kunsan Pohang Taegu end
```

Allocations to DCA indicate the regions over which to fly the DCA and the percentage of the DCA effort to expend in that region. For example,

```
order DPRK alloc DCA NKorea 80% YellowSea 10% JapanSea 10% end
```

Finally, allocations to airfield defense (AfldDef) identify airbases to be defended and the percentage of the AfldDef sorties to expend defending each airbase. For example,

```
order 7USAF alloc AfldDef Kunsan 20% Yechon 20% Taegu 20% end
```

Mission Timing

The final guidance required by the system to prepare the ATO is restrictions on when missions are to fly. Restrictions are placed by specifying the percentage of mission effort to be flown during each of the six 4-hour periods of the day, starting from 00:00 to 04:00. Since daytime is assumed to run from 08:00 to 20:00, the third through the fifth periods are in daylight. The percentages must again sum to 100. Even though the order allows any portion of the effort to be allocated to a single period, the ATO-generation process assumes that a single aircraft cannot fly more than a single sortie within a 4-hour period. A timing vector is specified for each mission type as follows:

```
set airwar 7USAF    cas_timing   0  0 30 40 30  0
set airwar 7USAF    bai_timing  20 10 20 20 20 10
set airwar 7USAF     ai_timing  15 10 25 20 25  5
set airwar 7USAF   sead_timing  15 10 25 20 25  5
set airwar 7USAF    dca_timing   5 10 25 25 25 10
set airwar 7USAF    dca_timing   5 10 25 25 25 10
set airwar 7USAF   area_timing   5 10 25 25 25 10
set airwar 7USAF  awacs_timing   5 10 25 25 25 10
set airwar 7USAF  sweep_timing   5  5 30 25 30  5
set airwar 7USAF attack_timing   5  5 30 25 30  5
set airwar 7USAF    oca_timing   0 10 40  0 40 10
set airwar 7USAF jstars_timing  20 10 20 20 20 10
```

Packaging

ITM air missions are *packaged* so that mission aircraft may be accompanied by escort, SEAD, ECM, and reconnassiance assets. Packaging varies according to the mission and can include the specification of a ranked set of alternatives. The packages are defined in a C-ABEL language table defined in the file ato.A, which can be found in the Force-C/A/Abel/Model directory. There are currently two packaging tables: level 1 represents packaging for high-threat environments; level 2 represents packaging for low-threat environments. The packaging table used by a theater side is changed with the parameter AIRWAR->pkg_set.

ATO Generation

With the guidance on rerole, apportionment, allocation, and mission timing, the simulation will generate the air tasking order for each command. Because air-to-ground sorties may require packaging that could affect the availability of air-to-air sorties, the air-to-ground missions are always packaged first for the ATO. Within the air-to-ground category, sorties are assigned to missions in order of

apportionment size: Missions with the largest apportionments get first call on the resources. For a particular mission, sorties are assigned to comply with the timing guidance given. However, when a small number of sorties are involved for a given mission in a given time period, the *granularity* of the process (or rounding) may produce an ATO that differs slightly from the proportions specified. Note that if insufficient escort or SEAD assets are available for packaging, fewer packages could be created than were planned for.

After all the air-to-ground missions are tasked, the air-to-air missions are filled, with the largest apportionments filled first. Detailed information on the ATO-generation process can be logged by setting the COMMAND->log_level parameter for a given air command to the value 5.

The ATO is generated after time 00:00 in the simulation; therefore, the first opportunity to examine the ATO is at 04:00. ATO generation can be forced at 00:00 hours with no time advance, using the FORCE->air_plan_now parameter. This parameter is used to iteratively adjust the planning guidance and examine the resulting ATO, without advancing model time.

An ATO summary can be called up with the itm-ato display. To see details on every package, use the Itm-ato display (with the *I* capitalized). For each of the six time periods, this display shows the squadrons that compose each package and the intended target. For CAS and BAI missions, the target type is initially listed as the name of the supported (friendly) command because the actual enemy unit to attack is not known at the time the ATO is planned. After the CAS or BAI mission is flown, the actual enemy unit struck is added to the ATO. This sequence is illustrated in Figure 5.5 for missions 104 and 105, for which CAS is flown in support of the command KS_1C against units of the North Korean 2nd Corps (2-CORPS).

Air Execution Overview

The execution of the air war is always between two theater-level commands. Although there are usually multiple subordinate air commands on each side, their ATOs are combined into two theater-level ATOs that are adjudicated period by period.

In each period, the air execution process is performed twice—once for each side's attacking packages against the other's ground-to-air defenses and defending packages.

```
7USAF ATOs for period 3 [beginning Day9,0800Z]:
 ID Squadron-Name        MDS     Mission A/C Target
 27 1-SFW/452-TFS        F-117   AI        2 SSAM_fixed/NKorea/NKorea
 28 4-TFW/334-TFS        F-15E   AI        4 SSAM_fixed/NKorea/NKorea
    18-TFW/44-TFS        F-15    Escort    1
 29 4-TFW/334-TFS        F-15E   AI        4 SSAM_fixed/NKorea/NKorea
    18-TFW/44-TFS        F-15    Escort    1
 30 4-TFW/334-TFS        F-15E   AI        4 SSAM_modern/NKorea/NKorea
    18-TFW/44-TFS        F-15    Escort    1
 31 4-TFW/334-TFS        F-15E   AI        4 SSAM_modern/NKorea/NKorea
    18-TFW/44-TFS        F-15    Escort    1
 79 8-TFW/13-TFS         A-16    OCA       4 Changjin_Up
    18-TFW/67-TFS        F-15    Escort    1
    8-TFW/13-TFS         A-16    SEAD      1
 80 8-TFW/13-TFS         A-16    OCA       4 Pukchang
    18-TFW/67-TFS        F-15    Escort    1
    8-TFW/13-TFS         A-16    SEAD      1
    .
    .
    .
104 355-TFW/15-TFS       A-10    CAS       4 KS_1C>>2-CORPS/56-ID
105 355-TFW/15-TFS       A-10    CAS       4 KS_1C>>2-CORPS/57-ID
106 355-TFW/15-TFS       A-10    CAS       4 KS_5C>>5-CORPS/66-ID
107 355-TFW/15-TFS       A-10    CAS       4 KS_5C>>5-CORPS/67-ID
119 301-TFW/457-TFS      F-16C   DCA       4 in theater
120 301-TFW/457-TFS      F-16C   DCA       4 in theater
121 301-TFW/457-TFS      F-16C   DCA       3 in theater
```

Figure 5.5—Air Tasking Order

Attacking packages encounter defenses in the following order:

- Attacking packages versus sweep packages
- SEAD packages versus barrier ground-to-air
- Attacking packages versus barrier ground-to-air
- Attacking packages versus area ground-to-air
- Attacking packages versus DCA packages
- OCA packages versus airfield-defense packages
- AI packages versus area-defense packages
- Attacking packages versus point ground-to-air packages.

Air Defense

Attacking packages encounter two types of defenses: air-to-air packages and ground-to-air defenses. Packages of the various air-to-air missions provide layers of defenses against attacking packages. Sweep packages engage all attacking packages; DCA engages all packages, except CAS, that penetrate their assigned region; area defense engages all AI packages; and airfield defense engages only the OCA packages attacking their assigned airbase.

To avoid the tactical problems of allocating different-strength defending packages against different-strength attackers, the total air-to-air score of all defenders is totalled and divided among the attacking packages. The total score for engaging the attackers is first reduced by an engagement rate based on the ratio of attacking to defending aircraft, and is modified by the presence of AWACS.

In the air-to-air engagement, the aggregate air-to-air scores of the defender and attacker packages modify standard loss rates for the escort, mission, and interceptor aircraft. Note that because this is an expected-value simulation, losses are spread evenly over all similar packages, resulting in a little damage to each. Although the total losses over the whole theater are appropriate (i.e., they are modeled properly), losses to any individual package are small. For the same reason, losses to a package are spread evenly over each package role. Therefore, package capability degrades evenly, without the catastrophic loss of an entire role. Figure 5.6 lists the parameters applying to air-to-air combat.

Barrier, area, and point ground-to-air defenses also provide a *layered* defense: Barrier defenses engage all attackers crossing a border, area defenses engage all but CAS and BAI that penetrate a region, and point defenses engage packages attacking airbases and fixed interdiction targets. Adjudication is done in two steps: for SEAD aircraft in all packages against the defenses, then for the suppressed defenses against all packages.

Each equivalent SEAD sortie kills a number of air defense radars according to parameters described in Figure 5.7. The additional suppression from the total

Name	Description	Default
esc-kill-int	escort loss rate by standard interceptor	.02
int-kill-esc	interceptor loss rate by standard escort	.02
int-kill-msn	mission aircraft loss rate by standard interceptor	.02
ingress-air	% of aircraft kills by air lost on ingress	80
awacs-engage	added fraction of defenders engaging with AWACS	.20

Figure 5.6—Air-to-Air Combat Parameters from the itm Table

damage done in the period is taken from a curve defined by parameters for the base suppression at 0 percent damage and the amount of damage that causes 100 percent suppression.

For the ground-to-air engagement, the density of air defense radars and the air-defense score are compared to standards to generate multipliers of a standard loss rate. In addition, attrition is reduced as the total number of attacking packages rises above the capacity of the defense radars to engage them. Figure 5.7 lists the parameters applying to ground-to-air combat.

The air defenses of a ground unit are calculated from the ground force air-defense equipment. The calculation of the number of radars, area covered, and air defense score depends on the parameters PARM->100 through PARM->104, and PARM->108, defined in file misc.sec. These scripts and parameters are listed in Figure 5.8.

Name	Description	Default
sam-supp-barr	% of radars killed to cause 100% suppression	40
sam-supp-area		40
sam-supp-point		33
suppress-base	% suppression of radars when not under attack	0
sam-loss-barr	number of radars killed per equiv. SEAD sortie	1
sam-loss-area		1
sam-loss-point		1
sam-dense-barr	standard radar/km density	.1
sam-dense-area		.0005
sam-dense-point		.1
sam-score-barr	standard SAM score at killing aircraft	.15
sam-score-area		.15
sam-score-point		.15
sam-kill-barr	aircraft loss rate by standard defenses	.5
sam-kill-area		1.0
sam-kill-point		.5
radar-eng-barr	maximum number of aircraft engaged per radar	2
radar-eng-area		2
radar-eng-point		2
ingress-sam	% of aircraft lost to SAM kills on ingress	60

Figure 5.7—Ground-to-Air Combat Parameters from the itm Table

Name	Description	Default
Creation scripts	from the sam table	
barrier-create	create barrier defenses between two regions	
area-create	create area defenses in a region	
point-create	create point defense at an airbase/generic target	
Numbered parameters from the parm table		
100	radars per OIR-Adef unit equipment	.1
101	OIR-Adef standard kill score	200
102	radars per Gdd-Adef unit equipment	.1
103	Gdd-Adef standard kill score	200
104	mult of kill score for survival score	1
108	area of 1 divisions air defenses	10

Figure 5.8—Ground-to-Air Defense Parameters

In addition to "real" damage, packages suffer "virtual" damage (sorties that abort) in a high-threat environment. Virtual damage adds to real damage when calculating aircraft arriving at targets. Figure 5.9 lists the parameters used to determine virtual sortie losses, which are in the airwar parameter table (which defines parameters for each air command).

Air-to-Ground Attacks

Choosing CAS and BAI Targets. CAS targets are selected only from the forces with which the frontal forces of the supported command are engaged. BAI targets are chosen to the rear of CAS targets along the defined path of the supported command out to a parameterized distance (initially 200 kms). Opposing units with at least a specified number of armored vehicles (parameters AIRWAR->cas_vehicles, bai_vehicles) are the priority targets for CAS and BAI. Units that meet these criteria are targeted first in the order of the most-armored vehicles in the original unit; if no units meet the criteria, units are targeted in the order of most-surviving armored vehicles.

The highest-ranked CAS target receives half the available CAS packages, the next target receives half of the remainder, and so on, with the exception that packages are not subdivided.

The number of packages each BAI target receives is determined by where the target sits in the BAI targeting zone and whether it is moving forward. The parameters AIRWAR->bai_fwd_kms and bai_bck_kms define the forward and back parts of the zone in which BAI targets are found, as illustrated in Figure 5.10. The parameters AIRWAR->bai_fwd_move, bai_fwd_still, bai_bck_move,

Name	Description	Default
virt-thresh	% damage above which virtual damage accrues	1
virt-loss	% virt damage per % real damage above virt-thresh	2

Figure 5.9—Virtual Damage Parameters from the airwar Table

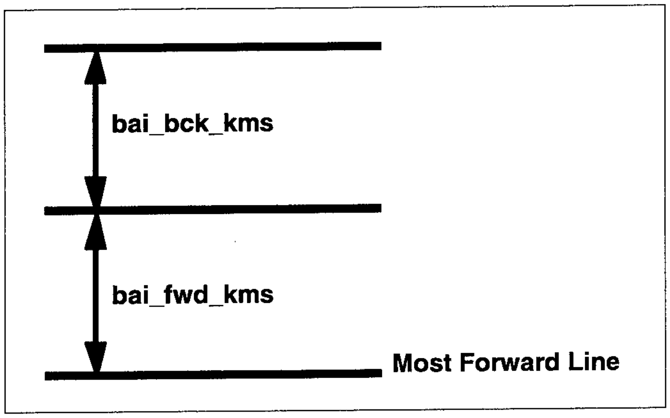

Figure 5.10—BAI Targeting Zones

and bai_bck_still specify the relative weight of effort given to moving and non-moving forces in the forward and back areas. These parameters are listed in Figure 5.11.

If either a CAS or BAI mission does not find a target, then a target is chosen from the other list. That is, CAS missions will automatically be converted to BAI missions or BAI missions to CAS missions. The itm-ato display will also switch the package definition, but it will put a tilde (~) before the mission type. Thus, in the itm-ato display, a mission shown as "~BAI" is a mission flown as a BAI mission but that was originally scheduled as a CAS mission.

Adjudicating Air-to-Ground Attacks on Ground Forces. This subsection describes the adjudication of a CAS, BAI, or AI package striking a ground force. The mission score of an air-to-ground package is given in terms of equivalent sorties, which are allocated among the vehicle, infantry, and artillery weapons of the ground force target.

The percentage of a CAS package that attacks artillery is specified by the parameter AIRWAR->cas_arty. The remaining sorties attack vehicles and infantry in proportion to their numbers, with infantry weapons divided by the parameter ITM->infty_allocs.

Name	Description	Default
cas_vehicles	minimum vehicles to be a desirable CAS target	40
bai_vehicles	minimum vehicles to be a desirable BAI target	40
bai_fwd_kms	depth of forward part of BAI targeting zone	100
bai_bck_kms	depth of back part of BAI targeting zone	100
bai_fwd_move	relative weight accorded moving forces in forward	10
bai_fwd_still	relative weight accorded still forces in forward	4
bai_bck_move	relative weight accorded moving forces in back	10
bai_bck_still	relative weight accorded still forces in back	1

Figure 5.11—Ground Force Target Selection Parameters from the airwar Table

The parameter AIRWAR->bai_arty specifies a percentage of BAI dedicated to artillery targets. The remaining BAI packages are allocated among vehicles, infantry, and artillery in proportion to their numbers, with infantry divided by ITM->infty_allocs.

AI packages attack vehicles, infantry, and artillery in proportion to their numbers, although the number of infantry is reduced in this weighting by applying the infantry divisor.

The weapons killed per equivalent sortie are set independently for each mission type and ground force posture (ITM->vehicle_kills and arty_kills), except that infantry kills are calculated as vehicle kills multiplied by parameter ITM->infty_kills.

In addition to equipment losses, air-to-ground attacks also slow the advance of the ground force's command, given as a number of hours' delay for each equivalent sortie attacking an equivalent division (ITM->ed_delay_hrs). The command cannot, however, be reduced below a minimum km-per-day speed (ITM->min_flot_kpd). These parameters are listed in Figure 5.12.

Choosing OCA Targets. If a list of explicit airbases is not provided as targets through the Allocate order, then the model will choose targets from the airbases in the target regions for the theater command. If the parameter AIRWAR->oca_priority is set to on, then those airbases are ranked according to the maximum BAI score among their based squadrons; if to off, they are ranked by intercept (air-to-air) score. Airbases that are damaged more than the value of parameter AIRWAR->oca_dam_crit are ranked last. These parameters are listed in Figure 5.13.

Adjudicating OCA Attacks on Airbases. Damage by OCA packages to airbases is divided among four categories: aircraft (sheltered and unsheltered), runways,

Name	Description	Default
airwar		
cas_arty	% of CAS equiv sorties that attack artillery	10
bai_arty	% of BAI equiv sorties that attack artillery	50
itm		
infty_alloc	infty equal to 1 vehicle when allocating sorties CAS 50 BAI 50 AI 50 Helo	20
vehicle_kills	kills per equiv sortie by target posture atta CAS 1.5 BAI 1.0 AI 1.0 Helo defend .6 .4 .4 delay 1.5 1.0 1.0 moving 1.5 1.5 1.5	.9 .4 .9 .2
infty_kills	vehicle_kills multiplier for infantry kills CAS 50 BAI 50 AI 50 Helo	20
arty_kills	kills per equiv sortie by target posture all postures CAS .4 BAI .25 AI .25 Helo	.4
ed_delay_hrs	hours delay by 1 equiv sortie per target ED CAS .083 BAI .04 AI .04 Helo	.083
min_flot_kpd	min FLOT speed below which cannot be delayed by air	5

Figure 5.12—Ground Force Attack Adjudication Parameters from the airwar and itm Tables

maintenance, and supplies. Supply damage from conventional attacks has not been implemented, so this damage is added to the maintenance category. Parameters PARM->106 and PARM->107 set damage rates for maintenance, and PARM->116–119 for runways. Parameters FORCE->at_risk, FORCE->shelt_per_std, and FORCE->ac_per_std determine aircraft vulnerabilities. Parameters PARM->120–128 are airbase class multipliers for runway damage (for example, using the values in Figure 5.14, it takes 400 standard weapons to cause 80 percent damage to a major military airfield, but only 80 standard weapons against a minor civilian airfield will cause 80 percent damage). These parameters are listed in Figure 5.14.

Adjudicating AI Attacks on Generic Targets

Air interdiction packages may also be allocated against generic targets, such as STOR_ammo or PROD_ammo. Each of these targets represents a number of sites

Name	Description	Default
oca_priority	rank airbases by max BAI score (on), or DCA (off)	on
oca_dam_crit	% damage above which the airbase is low priority	50

Figure 5.13—Airbase Target Selection Parameters from the airwar Table

Name	Description	Default
From the airwar table:		
oca_tgting	% allocation of damage among airbase facilities Ac/Shelters 100 Runway 0 Maintenance 0 Supply 0	
From the force table:		
ai-to-std	mult converting AI score to standard weapons	.5
lotech-to-std	mult converting lotech wpn score to std wpns	.5
hitech-to-std	mult converting hitech wpn score to std wpns	5.0
at_risk	fraction of tacair on base at attack time	.5
shelt_per_std	shelters destroyed per std wpn	.01
ac_per_std	unsheltered aircraft destroyed per std wpn	.05
Numbered parameters from the parm table:		
106	fraction of maintenance killed per std wpn	.00025
107	lowest allowable fraction of maintenance surviving	.10
116	fraction of runway damage per std wpn up to #117	.002
117	threshold of std wpns in attack between #116 and 118	400
118	fraction of runway damage per std wpn over #117	.00025
119	lowest allowable fraction of runway surviving	.10
120	runway damage divisor for MAIR_bomber	1.25
121	MAIR_c3	1.0
122	MAIR_major	1.0
123	MAIR_minor	.75
124	MAIR_spt	1.0
125	CAIR_major	.75
126	CAIR_medium	.5
127	CAIR_minor	.2
128	CAIR_small	.2

NOTE: "Ac/Shelters" is the abbreviation for aircraft and/or shelters. "spt" is the abbreviation for supporting airfields.

Figure 5.14—Airbase Attack Adjudication Parameters

that are not located on the network overlay; they are assumed to be distributed evenly throughout a region. Damage is calculated from a general nuclear damage model using weapon equivalent megatons (EMT; very small for conventional weapons) from weapon.sec and target type hardness from facility.sec.

Ports in JICM 1.0 are defined at individual JICM places. They may be targeted as generic targets, including all ports of the same type within a region, or they may be individually targeted at a specified place.

Air War Displays

Cumulative aircraft losses are found in the hist-air display, Figure 5.15. Losses are accumulated from the time the "his-init" command is given, for the commands listed in the following order:

```
set force his-init NKAF ROKAF 7USAF KUSNAV-AIR KUSMC-AIR end
```

The effects of the last period's air-to-ground attacks can be found in three sources, two of which are places on the map. First, when CAS and BAI packages that have been allocated to support a particular command are executed, a fire support symbol (a small yellow star) is displayed next to the name of that command on the map. Selecting the symbol with the mouse brings up a display that lists all fire support received by the command the last period. Figure 5.16 shows a sample BAI section from that display.

The second source of air-to-ground results is the map battle display, found by selecting the battle symbol at the point of contact between two opposing commands. This display primarily shows details of ground combat, but it also summarizes air-to-ground attacks. Figure 5.17 gives an example from the battle

Air History for ROKAF between Day3,0000Z and Day5,0000Z

A/C Class A/C MDS	Day3 Surviving	--- Day3 - Killed	Day5 --- Assigned	Day5 Surviving
Fighter	0	0	0	0
Multi	397	26	0	371
F-4	164	19	0	145
F-16C	116	3	0	113
F-5	117	4	0	113
Interdictor	0	0	0	0
CAS	22	0	0	22
A-37	22	0	0	22
Bomber	0	0	0	0
Other	67	0	0	67
Basw-hx	24	0	0	24
S-2	30	0	0	30
P-3	13	0	0	13
Total	486	26	0	460

NOTE: "Base-hx" denotes Blue ASW helicopter.

FIgure 5.15—hist-air Display

```
Air/Fires supporting any battles at front(s) of:
   KS_5C
  For 4 hours prior to Day3,0800Z

BAI:                                   Kills              A/C Losses
                 Launch  Arrvg  ------------------ ------------------
Aircraft   Owner Sortie EqSort  Armor Infanty  Arty  AirAir SfcAir Total
-------- ------- ------ ------  ----- -------  ----- ------ ------ -----
    A-16      US      4   3.97   0.44    9.29  0.60   0.02   0.17  0.19
    A-37  SKorea      4   1.34   0.15    3.13  0.20   0.05   0.14  0.19
           TOTAL      8   5.31   0.59   12.42  0.80   0.07   0.31  0.38
```

Figure 5.16—Fire Support Display

```
Air-gnd        eq  loss-from  --kills--         eq  loss-from  --kills--
Support sort sort ftrs sams veh inf art  sort sort ftrs sams veh inf art
BAI      2.3  1.1 0.07 0.12   0   1   0   7.1  4.9 0.09 0.30   1  12   1
```

Figure 5.17—Air-to-Ground Support Section of the Battle Display

display, showing for the attacker and the defender the arriving sorties and equivalent sorties, sorties lost to air-to-air and ground-to-air defenses, and resulting kills of vehicles, infantry, and artillery.

The third source of air-to-ground results is additional detail written to the ,log file through the log-level instruction, which sets a numeric log level (0 to 5) for ground and air commands.

Setting the log level for an air command, such as ROKAF, to level 2,

```
set command log-level ROKAF 2
```

will log statements about every ROKAF air-to-ground attack:

```
Note: 1-TFW/115-TFS attacks 4-CORPS/1-MXB with 8/8.0/2.8 sorts sent/tgt/eq
Posture=attk, inf_alloc=50.00 inf_kill= 50.00 arty_pct=0%
  #Tgts: 135.7 vehcls, 2886.1 infty, 53.9 arty, 0.1 deadv
  ESort: 1.53 vehcls, 0.65 infty, 0.61 arty
  K/Srt: 1.00 vehcls, 50.00 infty, 0.20 arty
  Kills: 1.53 vehcls, 32.65 infty, 0.12 arty, 0.0 deadv
Note: 1-TFW/115-TFS delays 4-CORPS/1-MXB 0.51 hours with 8.0/2.8 sorts on-tgt/eq
```

Log level 3 for an air command summarizes the efficiency of the ATO creation, showing the number of sorties required by guidance and the number actually filled, and the list of available squadrons and extent to which they were used. Log level 4 or 5 also gives voluminous detail on the creation of each individual package.

Log level 3 for a theater command, such as CFCK, traces the execution of penetrating packages versus that of defending packages and ground-to-air

defenses. Figure 5.18 shows the log of the adjudication of CFCK packages attacking DPRK over one period. The sections of this display are as follows:

ATO Lists: Lists of attacking and defending packages that are flying this period. An entry for each filled role in the package gives total sorties and the equivalent-sortie score of each sortie.

Ground-to-Air Encounters: There are separate sections for barrier, area, and point defenses, and for each of these a section on SEAD attacking the defense and the defense attacking the packages. The heading "%-thru" is the percentage of packages that fly through that defense; but because this is an expected-value model, each package encounters all barriers, and losses are multiplied by this percentage. The "mults" columns are the calculated multipliers of the standard package loss rate: "radar" for radar density, "GAeff" for the SAM effectiveness score, "SEAD" for the suppression by SEAD this period, and "satur" for the saturation of the radars.

Air-to-Air Encounters: There are separate sections for sweep, DCA, area-defense, and airfield-defense missions, if any of these missions are flying. The column "score-per-pen" gives the defensive equivalent sorties allocated per penetrating aircraft, and "AA-score" gives the total air-to-air scores of the penetrating package and the defensive sorties allocated against it. Percentage losses are listed separately for the defending sorties, and for the escort and mission sorties of the attacking package.

Virtual Attrition: This section lists additional attrition representing degradation of capability because of high threat and losses, and final sorties on target.

```
Air Battle CFCK attacking DPRK

CFCK ATO
          Roles (sorties/score)                               Vuln Mission Esc
Pkg  Mssn  Mission  Escort   SEAD     ECM      Recce              A-G G-A A-A
 0    BAI  2/0.8    2/0.4                                         1.0 0.5 2.0
 1    BAI  2/0.8    2/0.4                                         1.0 0.5 2.0
 2    OCA  4/27.5   1/0.6    1/27.5                               5.0 5.0 1.0
 3    OCA  4/27.5   1/0.6    1/27.5                               5.0 5.0 1.0

DPRK ATO
          Roles (sorties/score)                               Vuln Mission Esc
Pkg  Mssn  Mission  Escort   SEAD     ECM      Recce              A-G G-A A-A
 0    DCA  4/0.5                                                  2.0 1.0 0.0
 1    DCA  4/0.5                                                  2.0 1.0 0.0
 2    DCA  4/0.4                                                  2.0 2.0 0.0

Attack Barrier G-A
                        %   sead  radars
  pkg region1 region2 thru score #  kills
  2   SouthKo NorthKo  100 27.5   30  0.4
  3   SouthKo NorthKo  100 27.5   30  0.4

Encounter Barrier G-A
                        %    %       ------mults-------
  pkg region1 region2 thru loss  radar GAeff SEAD  satur
  0   JapanSe NKorea    20  0.1  0.25  1.00  1.00  1.00
  0    SKorea NKorea   100  0.8  2.00  1.00  1.00  0.97
  1   JapanSe NKorea    20  0.1  0.25  1.00  1.00  1.00
  1    SKorea NKorea   100  0.8  2.00  1.00  1.00  0.97
  2   JapanSe NKorea    20  0.1  0.25  1.00  1.00  1.00
  2    SKorea NKorea   100  0.8  2.00  1.00  1.00  0.97
  3   JapanSe NKorea    20  0.1  0.25  1.00  1.00  1.00
  3    SKorea NKorea   100  0.8  2.00  1.00  1.00  0.97

Attack Area G-A
               %-thru  sead  radars
  pkg region   reg def score #  kills
  2   NorthKo 100  90 27.5  45  0.4
  3   NorthKo 100  90 27.5  45  0.4

Encounter Area G-A
              %-thru   %    ------mults-------
  pkg region reg def loss  radar GAeff SEAD  satur
  2   NKorea 100  90  0.2  0.53  1.00  1.00  1.00
  3   NKorea 100  90  0.2  0.53  1.00  1.00  1.00

Penet vs DCA
AWACS 0, engage-rate 0.64, dca-score-per-pen 0.115
        AA-score  %-loss (w/o vuln)
  pkg dca    pen    dca esc msn
  0   0.46  0.92    4   6   1
  1   0.46  0.92    4   6   1
  2   0.69  0.60    2  11   2
  3   0.69  0.60    2  11   2
```

Figure 5.18—Trace of Air Execution in ,log File

```
Attack Point G-A
      sead  radars
  pkg score #  kills
  2   27.5   2  0.4
  3   27.5   5  0.4

Encounter Point G-A
       %       ------mults-------
  pkg loss  radar GAeff SEAD  satur
  0     2.8  2.00  0.19   1.00  1.00
  1 no defenses
  2     0.1  0.10  1.00   1.00  0.68
  3     0.1  0.15  1.00   1.00  0.69

Virtual attrition
pkg real  virt  sorts
 #  attr  attr  on-tgt
 1  0.10  0.10   1.85
 2  0.07  0.04   1.90
```

Figure 5.18—Trace of Air Execution in ,log File (cont'd)

6. Naval and Amphibious Operations

John Schrader

JICM 1.0 includes a model of amphibious warfare. Previous RSAS versions have included Marine ground and air forces, maritime prepositioning ships (at a nominal level of detail), amphibious ships, and general sealift and airlift capabilities. The JICM contains specific models for over-the-beach operations as an integrated part of the ITM combat models. The JICM data base contains representative data for Marine Air-Ground Task Force (MAGTF) operations based on inputs from Headquarters, U.S. Marine Corps. As with all JICM models, this initial amphibious operations capability will be modified and improved as JICM users apply the system to analysis, training, and planning problems.

Amphibious warfare doctrine is based on a sequence of phases in which Marine units increase readiness, deploy to embarkation ports, load troops and equipment onto ships or aircraft, move to a rehearsal area in a forward theater of operations, conduct a rehearsal landing, transit to an Amphibious Objective Area (AOA), deliver the landing force with landing craft or helicopters, transfer command ashore, conduct operations in conjunction with other ground forces, and reembark onto ships for return to home bases. Each of these phases can be represented in JICM 1.0. To introduce the amphibious models and describe some of the naval force model enhancements, we use an example based on a Global 92 scenario to proceed phase by phase through amphibious operations.

Scenario Background

One possible future major regional contingency could arise from problems of access to water in the Tigris and Euphrates river basins, shown in Figure 6.1. Turkey has begun to construct a network of dams and hydroelectric power plants to improve the economy in its southeastern quarter. Water retained in Turkish lakes is not available for irrigation and other purposes downstream in Syria and Iraq. Turkey's economic policy could lead to Syrian and Iraqi military operations to gain control of or destroy the dams and their power plants. The

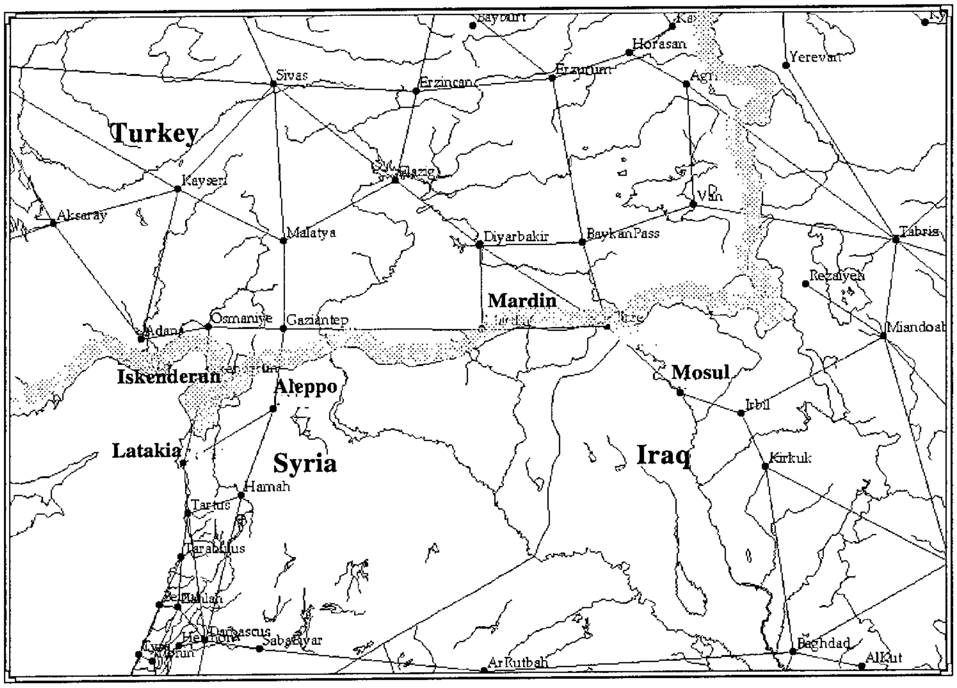

Figure 6.1—Tigris-Euphrates Theater of Operations

scenario[1] includes a campaign plan in which Syrian forces advance on two axes, one coastal (the JICM command is named S-Gates) and one proceeding from Aleppo into Turkey west of the Ataturk Dam (S-Aleppo), as shown in Figure 6.2. Iraqi forces enter Turkey north of Mosul and proceed toward the Turkish city of Elazig in the heart of the water development region. The principal Iraqi command is S-Mosul; a smaller offensive force (S-Cizre) will conduct operations in eastern Turkey near Lake Van.

The attack uses modern mechanized ground forces to sweep rapidly through the plains of southern Anatolia. Operations by Turkish forces focus on defense of key mountain passes, where attacking tanks are less effective, and rely on heavy air support from the United States to inflict unacceptable losses on advancing forces. Successful amphibious operations in the rear of Syrian forces, landing near the port of Latakia, could cause the rapid collapse of Syrian forces engaged in the mountains south of the Turkish port of Iskenderun. The U.S. concept of operations for the amphibious force (TUS-amph) is to land a Marine regiment south of Latakia, defeat local defending forces, then capture the port of Latakia, where the remainder of a Marine Expeditionary Force (MEF) would conduct an

[1]See John Y. Schrader, *Global 1992 Analysis of Prospective Conflicts in the Tigris-Euphrates Watershed*, RAND, N-3545-NA, 1993.

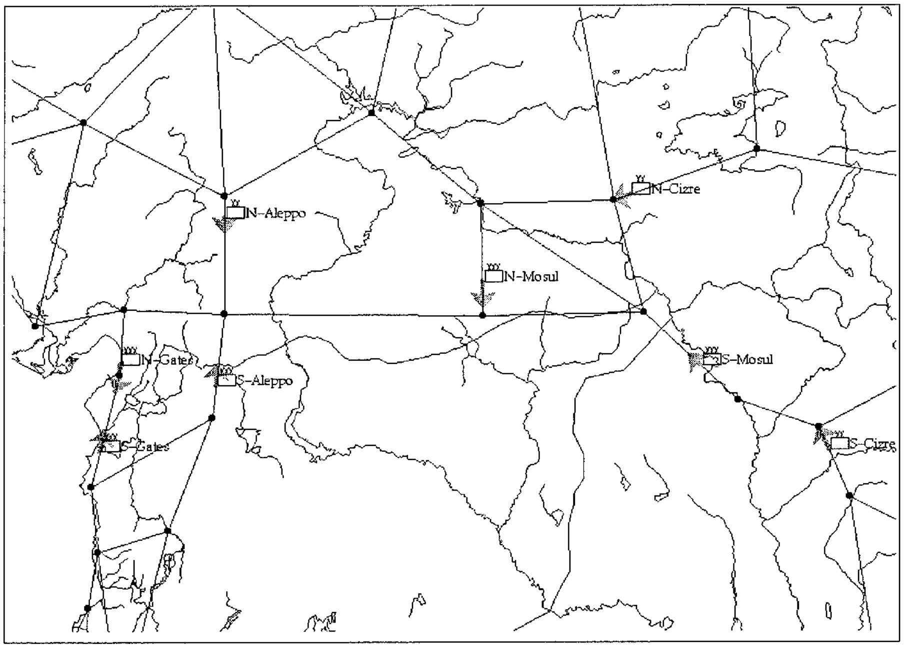

Figure 6.2—D-Day Command Positions

administrative landing before proceeding to sweep across the rear of Syrian and Iraqi forces.

Forming and Deploying an Amphibious Force

Joint Amphibious Planning Doctrine includes seven stages of operations. The first two are training, and assembly and movement to the rehearsal area. In the JICM, training levels are incorporated in the data that define Marine units. Times from alerting to achieving operational readiness are modeled for all ground forces and are not unique to the amphibious models. Assembly and movement to the rehearsal area are unique activities that can now be treated directly. The JICM data base consists of ships that now include a new "amphib" ship type with information on troop capacity and vehicles for amphibious assault. The data base also contains Marine ground and air units with combat characteristics that have been modified to be consistent with the new Integrated Theater Models for ground combat.

Figure 6.3 shows some of the information available to a JICM analyst in building an amphibious operations plan. The peacetime location of Marine and amphibious shipping can be determined using the new JICM Map graphics. JICM Map can zoom in on an area, such as the southeastern United States, and

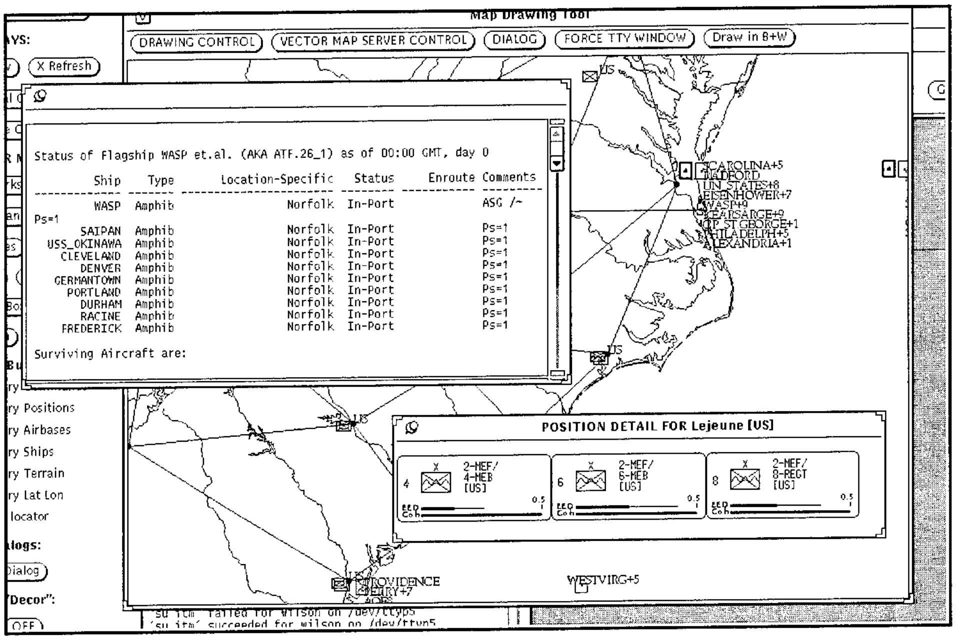

Figure 6.3—Original Position of Amphibious Units

positional data for forces can be shown and queried for more detail. In this case, the Marines at Camp Lejeune are represented by two Marine Expeditionary Brigades[2] and an independent regiment. Naval units in Norfolk are illustrated, with a query on the detailed composition of one of the default amphibious groups. Marine aircraft squadrons and their status could also be queried by displaying airbase details.

JICM operations are keyed to commands. In this example, the command defending the Turkish dams and Turkish territory is AG-Turkey. The opposing Iraqi-Syrian coalition is FR-Turkey. Amphibious forces participating in operations in the theater must be subordinated to theater commands. It is representative of real-world considerations to build an amphibious command, TUS-amph, and subordinate it to the theater command; the default command data have TUS-amph in them; if not, such a command can be subordinated to AG-Turkey by typing

```
set command create TUS-amph AG-Turkey Turkey
```

[2]At the time this documentation was originally prepared, Marine Expeditionary Forces (MEFs) usually consisted of two Marine Expeditionary Brigades (MEBs) and a separate Marine regiment. Since that time, the separate brigade headquarters have been dissolved, leaving most MEFs to consist of several Marine regiments.

U.S. forces must be allowed to operate under the theater command. Control of U.S. forces is turned over to that command by typing

```
order US control AG-Turkey
```

Since the Marine forces we want to use are part of the 2nd MEF (2-MEF), a single order can be used. The following orders unassign U.S. forces from their default assignments and set the stage for amphibious operations by (1) assigning the 2-MEF to the Turkish amphibious command, (2) assigning the carrier Forrestal to the theater, (3) putting the Forrestal air wing under a naval air command for the theater, (4) assigning Atlantic Fleet amphibious task groups to support the theater, and (5) alerting the U.S. naval forces:

```
order US unassign troops  -  -
order US assign 2-MEF                   TUS-amph
                  (4 forces affected)
order US assign 2-MAW                   TUSMC-air
                  (14 forces affected)
order US assign G.WASHINGTON            AG-Turkey
order US assign G.WASHINGTON-AW         TUSNAV-air
                  (7 forces affected)
order US assign ATF.26_1                AG-Turkey
order US alert  navy
                  (US navy alerted)
a d3
```

The naval air units in the Mediterranean are part of the theater air operations, so they are assigned to a separate command TUSNAV-air. The joint air tasking order will use carrier-based aviation units for general support until amphibious operations begin; then priorities and tasking can be revised. Because one of the amphibious ships in ATF.26_1 is represented as being in a short (3-day, "d3") maintenance, the U.S. Navy also needs to be alerted and the clock advanced three days for that ship to be ready.

Amphibious forces need a place to land. Many ports for administrative landings already exist in the JICM 1.0 data base, but amphibious landing areas need to be defined explicitly. The order to define a beach and the responses from the JICM models are

```
set beach Latakia create
Latakia-beach landings (35.5N  35.9E) staged from EMed/16 (35.5N 35.5E)
set beach Latakia-beach position Latakia/10/Tartus
Latakia-beach landings (35.5N  35.9E) staged from EMed/16 (35.5N 35.5E)
```

The first order creates a beach with the name Latakia in the vicinity of the place Latakia. The second command specifies where along an existing axis between the cities of Latakia and Tartus the landing force will transition into the ground combat network. The response to the orders identifies the seabox where amphibious ships supporting the landing will be located. The user may also specify the width of the beach (the default is 20 km), the distance from the beach to the network (the default is 5 kilometers), and the quality of the beach for amphibious landings ("good" or "poor"). The landing will be opposed by (the defenders of the beach will be) any opposing unit along the network that is located within the width of the beach.

After identifying forces that will participate in amphibious operations and defining one or more potential landing zones, it is necessary to embark the Marines and their equipment on amphibious ships. Embark is a new order in JICM 1.0. It requires the identification of a ground force, amphibious shipping, and a location; it is coupled with a "when" condition and a Route order for the amphibious group:

```
     order US embark 2-MEF/6-MEB ATF.26_1 Lejeune -
   Note: WASP deploys to Lejeune at Day3,0000Z
   Note: SAIPAN deploys to Lejeune at Day3,0000Z
   Note: NASSAU deploys to Lejeune at Day3,0000Z
   Note: USS_NASHVILLE deploys to Lejeune at Day3,0000Z
   Note: C_HALL deploys to Lejeune at Day3,0000Z
   Note: WHIDBY deploys to Lejeune at Day3,0000Z
   Note: ASHLAND deploys to Lejeune at Day3,0000Z
   Note: USS_PENSACOLA deploys to Lejeune at Day3,0000Z
   Note: PORTLAND deploys to Lejeune at Day3,0000Z
   Note: DURHAM deploys to Lejeune at Day3,0000Z
   Note: EL_PASO deploys to Lejeune at Day3,0000Z
   Note: SPARTANBURG deploys to Lejeune at Day3,0000Z
   Note: BARNSTABLE_C deploys to Lejeune at Day3,0000Z
   Note: HARLAN_CTY deploys to Lejeune at Day3,0000Z
   Note: SAN_BERNADNO deploys to Lejeune at Day3,0000Z
   Note: FAIRFAX deploys to Lejeune at Day3,0000Z
   Note: MCCLUSKY deploys to Lejeune at Day3,0000Z
   Note: DDG70 deploys to Lejeune at Day3,0000Z
   Note: CARNEY deploys to Lejeune at Day3,0000Z
   Note: KAISER deploys to Lejeune at Day3,0000Z
   Note: LENTHALL deploys to Lejeune at Day3,0000Z
   Note: KEARSARGE deploys to Lejeune at Day3,0000Z
   Note: 5000 of ATF.26_1's 5076-troop capacity will be
 used
           (1 force and 1 task group affected.)
     when ATF.26_1 embarked \
           order US route ATF.26_1 - Latakia-beach end
```

Only a few representative places in the United States are used in the default data base; Lejeune is used to represent both Camp Lejeune and Morehead City. If it were considered important to have additional locations for embarkation (e.g., Morehead City), they could be added to the user's data base (in data file place.unc).

Notes following the Embark order reflect the ships participating in the operation and the capacity of the group relative to the movement requirement. A second feature of the JICM 1.0 amphibious models is the "when" conditional order. Embarkation times are dependent on the movement of both ships and ground units to the embarkation port and may not be the same from one case to another. Here a Route order is given along with the Embark order, but it is not executed until all forces are embarked. Although the Route order specifies Latakia-beach as the destination, the model will deploy ships to the previously identified seabox associated with the beach.

Log-level settings can be used to monitor the progress of amphibious operations. In this example, the following orders were given at the beginning of the run to set the logging instructions to the highest-possible level for elements of 2-MEF:

```
set unit log 2-MEF  US 5
```

For the amphibious component, the logs generate outputs as the clock advances (this is a subset of the messages):

```
        a d7
                 Advance 24:00 hours to Day 4,0000Z
Note: KEARSARGE (ATF.26_1) arrives Lejeune at Day3,1813Z to embark 2-MEF/6-MEB
                 Advance 12:00 hours to Day 4,1200Z
                 Advance 12:00 hours to Day 5,0000Z
                 Advance 12:00 hours to Day 5,1200Z
Note: 2-MEF/6-MEB (ATF.26_1) is at SPOE at Day5,0000Z
Note: 2-MEF/6-MEB begins loading in Lejeune at Day5,1200Z
                 Advance 12:00 hours to Day 6,0000Z
                 Advance 12:00 hours to Day 6,1200Z
                 Advance 12:00 hours to Day 7,0000Z
                 Advance 12:00 hours to Day 7,1200Z
                 Advance 12:00 hours to Day 8,0000Z
                 Advance 12:00 hours to Day 8,1200Z
                 Advance 12:00 hours to Day 9,0000Z
                 Advance 12:00 hours to Day 9,1200Z
                 Advance 12:00 hours to Day 10,0000Z
Note: Embarkation of 2-MEF/6-MEB (ATF.26_1) at Lejeune complete at Day9,1800Z
  -> ATF.26_1 has embarked, triggering the following order:
  order US route ATF.26_1 - Latakia-beach end
                 (1 flagships and 21 others affected.)
```

Not all Marine forces move by amphibious lift. In this example, the remainder of 2-MEF is deployed by sealift to the Turkish port of Adana, awaiting capture of Latakia by 6-MEB. Once the port is captured, they will move to Latakia and form 2-MEF as a part of the command AG-Turkey. Orders for this movement include

```
    o US deploy 2-MEF/4-MEB     Adana   -
                            (1 forces affected)
    o US deploy 2-MEF/8-REGT    Adana   -
                            (1 forces affected)
    a d3
2-MEF/4-MEB [US] ready at Lejeune Day12,1200Z
2-MEF/4-MEB [US] leaves Lejeune Day12,1200Z
    .
    .
    .
```

Rehearsal and Movement to the AOA

Amphibious doctrine includes as the third stage of operation a rehearsal landing prior to combat operations. In this example, we have not used a specific rehearsal operation. More-detailed examples would embark forces, route them to a rehearsal area, delay an appropriate period of time, then route the forces to a beach (AOA).

AOA Pre-Assault Operations

The fourth stage of operations in joint amphibious doctrine is when beach-preparation operations occur. For JICM 1.0, air forces are the principal fire support forces. An air tasking order is used to allocate available forces to interdiction missions; the required orders are found in file Run/Plan/turkey.dday. An example of the effect of committing carrier aviation to suppress defenders is shown in the following log extracts:

```
Note: G.WASHINGTON-AW/3-AS attacks SYR-ARMY/5-MECD with 4/3/6 sorts sent/tgt/eq
Posture=attk, inf_alloc=50.00 inf_kill= 50.00 arty_pct=10%
  #Tgts: 614 vehcls, 2951 infty, 150 arty, 0 deadv
  ESort: 5.0 vehcls, 0.4 infty, 0.6 arty
  K/Srt: 1.5 vehcls, 75.0 infty, 1.00 arty
  Kills: 7.5 vehcls, 30.0 infty, 0.6 arty, 0.0 deadv
```

AOA Assault

When the amphibious forces are in place and the defenders have been sufficiently damaged or confused, a landing occurs (the fifth stage of the

operation). The orders causing a landing include an Orientation (direction) for the force once ashore, a Land order specifying who is to land where, and, in this example, Allocate and Apportion orders to reassign all Marine aircraft to support of the landing force:

```
set command orientation TUS-amph  (5 kms) Gates-
LOC(Latakia/10/Tartus)
        o AG-Turkey land ATF.26_1 combat Latakia-beach TUS-amph
        o TUSMC-air apport air-gnd 100 0 0 0 0 0
        o TUSMC-air apport air-air 0 100 0 0 0 0 0
        o TUSMC-air allocate CAS TUS-amph 100% end
```

The landing will result in losses to defenders and to the landing force based on the strengths of the opposing forces and the status of prepared defenses. Examples of reports on landing activity are

```
S-Gates has 2 forces on Tartus/(0-20)/Latakia
2-MEF/6-MEB comes ashore at Latakia/15.0Kms/Tartus, assigned to TUS-amph
      2000 troops come in LCACs/landers
          LCACs available for x troops, speed = a km/hr
          landers available for y troops, speed = b km/hr
          landing required z cycles, c hrs
          2-MEF/6-MEB losses = p%, defender losses=q% to r EEDs
```

Lodgment

The sixth stage of amphibious operations is the lodgment, when a support base is built by continued movement of men and equipment to the beach but combat occurs primarily among units on the ground. The length of this phase is controlled by the JICM analyst. It will continue until the force is given new tasking.

Figure 6.4 shows positions of theater forces immediately after the amphibious landing, including the position of the amphibious task force. After the defending forces are overcome, the force needs additional orientation to participate in theater ground operations. The command retains its identifier, TUS-amph, but is now treated as any other ground command. Necessary orders include

```
o TUS-amph command-mission main  Gates-LOC(Iskenderun/20/Latakia) 5 - -
   Note: 1 current mission(s) will be canceled
o TUS-amph gnd front 2-MEF/6-MEB US  - - - - -
   Note: TUS-amph's front contacts S-Gates's rear at Iskenderun/37.3Kms/Latakia at Day39,1136Z
```

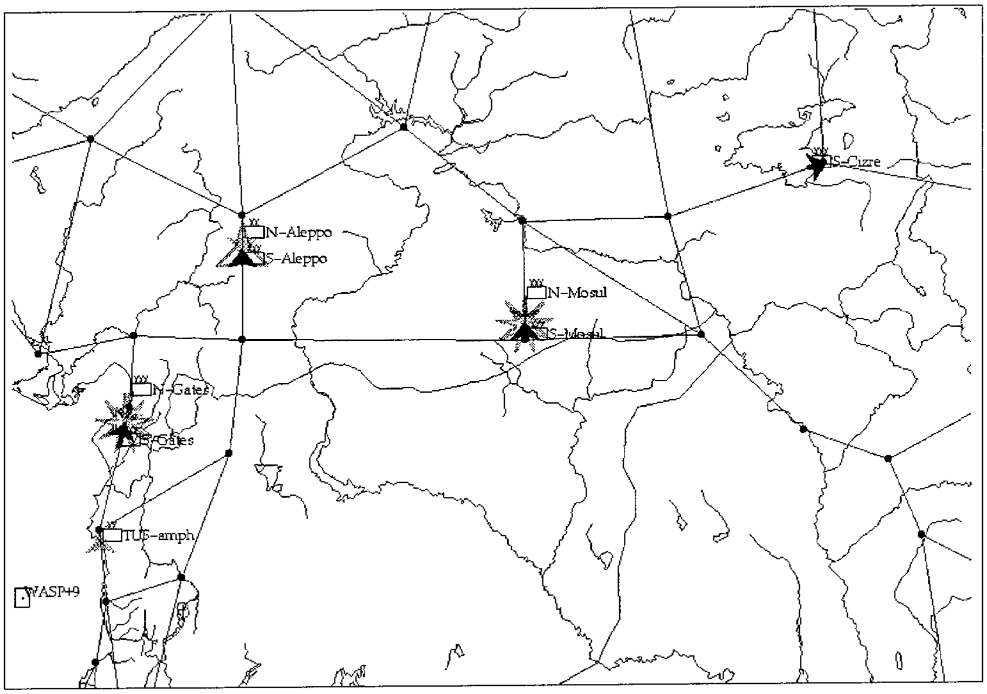

Figure 6.4—Positions After Amphibious Assault

The current procedures for deploying the follow-on units of the 2nd MEF are somewhat limited. In JICM 1.0, they must be script-deployed to the amphibious operating area using such instructions as[3]

```
set force gnd_move 2-mef/4-meb  us latakia/17.5/tartus 0
set force gnd_move 2-mef/8-regt us latakia/17.5/tartus 0
set force gnd_move 2-mef/26-meu us latakia/17.5/tartus 0
```

Retrograde

The final, seventh, stage is the reloading of forces on amphibious ships or general sealift for return to home bases or to other beachheads. The Embark order is used both for the initial embarkation near training bases and for retrograde operations in theater. If forces are to be returned using regular sealift, the Deploy order is appropriate.

[3]If any of these units is still in the process of moving to Turkey or unloading at ports in Turkey, a command of the form, "**set force stop_move 2-mef/4-meb us**" must first be sent. JICM 1.0 does not allow a new Deploy order to override a previous Deploy order; to override the previous Deploy order, a "stop_move" must be entered.

Future Developments

The role of mines in delaying or crippling amphibious operations needs to be represented in the JICM. For now, mines can be applied to choke-points but not to beaches or beach approaches. Future development plans include enhancing naval models to better represent littoral operations. Mine model enhancements will be included in this work. Additionally, the parameters for attrition in over-the-beach models need to be displayed so that users can easily adjust them to reflect operational experience or the needs of a specific analysis.

7. Mobility and Logistics

Carl Jones

The implementation of the ITM has resulted in a number of major changes in the mobility and logistics models. This section briefly outlines those changes as of JICM 1.0; detailed documentation will be published later. ITM conversion is essentially complete, and JICM 1.0 is lacking only two models that would have been considered available at least in some applications in the RSAS:

- The JICM full system is not a complete version of the old ABEL models, and, therefore, there is no Lift-Commander model. Analysts must be sure to explicitly assign airlift and sealift, as desired, in their scenarios.
- There is no longer explicit consumption of POL products as there once was in the CAMPAIGN-ALT model.

Mobility Modeling Changes

In the RSAS, all movement of forces was invoked using the Deploy order. With the reorganization of geographic modeling needed for ITM, it became desirable to restrict the use of Deploy. As of JICM 1.0, the *mobility interfaces* (orders used to direct forces to relocate) are as shown in Table 7.1. The syntax of all these order types and script interfaces is detailed in the on-line documentation system, which can be accessed from the *Force window* (the computer window in which the model runs) by typing "document orders <order-name>" or "document parameters <table-name> <keyword-name>", as desired. However, the Deploy and Route orders offer such a significant increase in user control over force movements in the RSAS that they are worth discussing here.

Both the Deploy and Route orders now have provision for specifying departure and arrival times in various contexts. There are two ways of specifying *game times*—the clocks maintained by the simulation, which can be advanced one day or more in a few seconds of real time—at the Force window interface. A *force time group* (FTG) is a game time stated in game days in the format "DayN,hhmmZ" (e.g., Day12,0800Z), or in terms of a contingency event time if an event has been defined with parameter FORCE->day (e.g., D+3,0800Z). Alternatively, a standard *date time group* (DTG) can be used by those who keep track of game time as "game date" rather than "game day," in the format

Table 7.1

JICM 1.0 Mobility Interfaces

Object to Be Moved	Order Interface	Script Interface TABLE->keyword
Army or Marine Deployment	Deploy	FORCE-> gnd_move
Amphibious Force	Embark/Route/ Land	FORCE-> gnd_embark FORCE-> ves_move
POMCUS or MPS Use	Employ	n.a.
Air Force Deployment	Deploy	FORCE-> air_move
Naval Ship Deployment	Route	FORCE-> ves_move
Materiel or Supply Movement	Resupply	GROUND->supply SUPPLY->gnd_owner SUPPLY->gnd_intop SUPPLY->atk_helo SUPPLY->weapon_type
Mobile Missile Deployment	Deploy	FORCE->msl_move (> 5.0)

NOTE: *Order interfaces* cause explicit simulation (for example, Deploy causes a force to move on and consume the capability of lift assets). *Script interfaces* cause instantaneous movement without consideration of the feasibility of the movement or the capacity of lift assets.

"ddhhmmZMMMYY" (e.g., 130400ZJun98 means 0400 Hours GMT [Greenwich Mean Time] on 13 June 1998). Note that although any legitimate time of day may be stated in these responses, time increments other than an even 4 hours (0000, 0400, 0800, 1200, 1600, and 2000) may not have any effect because the clock advance time (delta t) of air, land, and naval models is 4 hours under ITM. For example, ordering a naval task group to arrive at some position at, say, 1030Z will cause it to select a speed to arrive at that time but will otherwise probably have the same effect as ordering it to arrive at noon, since the simulation model executions prior to noon run from 0800Z, at which time the task group will not yet have arrived.

Deploy Orders

Deploy is now used only for ordering ground force (Army and Marine units) and air force (Air Force and Naval Air units) deployments. The syntax has changed little for air force deployments, but for ground force deployments it has been enhanced significantly. Prior to the JICM, all that could be stated was a destination; the user had limited control over how the force got there other than specifying airlift or sealift when relevant. Although the capability to order simple deployment still exists, much more significant route control is now also available. The Deploy order destination field for a ground force can now be a detailed deployment path (as described in Section 3). For example, ordering a ground force along the path "Washington>Richmond>Norfolk>Savannah"

instructs a force to move from its origin position (which might be anywhere in the world) to places Washington, Richmond, and so forth until the last-named place (or between-place location) is reached.

Such a destination field path can also have other mobility-related special instructions embedded in the path string. For example, if the U.S. 24th MXD (near Savannah) were ordered to deploy to LosAngeles, the default logic would simulate the movement across the U.S. road and rail network. If, instead, a movement by sea were desired, the destination path string could be stated as Jacksonville>sealift>LosAngeles, which would force a sea movement leg that would use the port of Jacksonville as the seaport of debarkation (SPOD) (instead of the more obvious port of Savannah) since it is explicitly stated. Table 7.2 shows the mobility instructions that can be used (embedded) in a destination path string.

The Deploy order "mode" field has also been enhanced and now includes the capability for the analyst to control a wider variety of mobility simulation factors. Table 7.3 highlights most of the new capabilities.

Example of Deploy

The following is a complete example of a Deploy order of the 1-CAV/1-ARMB from its home base in Texas to Taegu, South Korea. The following situations are

Table 7.2

JICM 1.0 Special Mobility Instructions

Instruction	Meaning
airlift or byair	Proceed by airlift, and if not already at an airport, proceed to the one most logical.
sealift or bysea	Proceed by sealift, and if not already at a seaport, proceed to the one most logical.
strategic	Select airlift or sealift depending on the default mode for the type of ground force.
administrative	Move nontactically on organic transport.
rail	Move as though by rail. No explicit simulation in JICM 1.0.
assisted	Move as though aided by non-organic transport (e.g., HETs). No explicit simulation in JICM 1.0.
tactical	Move as though contact or air attack may occur.
follow	At completion of deployment, if not collocated with the assigned command, proceed to join that command.

NOTE: An HET is a heavy-equipment transporter.

Table 7.3

JICM 1.0 Deploy Order Mode Instructions

Instruction	Meaning and Default (where not obvious)
- (dash)	Use default guidance for every decision.
airlift/sealift	Use named strategic mode for this move. The default is the force type's default mode.
surface/sfc	Same as sealift mode above.
rdd=N	Assign priority number N to this move. The default is to move in the sequence ordered.
force	Ignore government attitudes for routing this move. The default is to not violate borders.
tkr/notkr	Assume/ignore tankered load tables for this move. The default is to use the mobility tankering model.
suez/czone	Use of the named canal mandatory for this move. The default is to follow the government policy on canal transit.
use_suez/use_czone use_canals	Use of named canal(s) authorized if advantageous. The default is to follow the government policy.
avoid_suez avoid_czone avoid_canals	Use of named canal(s) forbidden for this move. The default is to follow the government policy.
convoy	No ship involved in a force move departs SPOE until all ships are loaded. The default is each ship sails when loaded.
serial	Subordinate units (brigades) move in tandem. The default is simultaneous movement.
FTG or DTG	Earliest departure time that may be used. The default is "now" (current game time).
dos=N	Force will move with N days of supply. The default is current on-hand level of supply.
eber=N/dber=M	Use no more then N berths at SPOE (M berths SPOD). The default is use any berths available.
maxfss=N	Maximum number of fast sealift ships/large, medium-speed RoRo (FSS/LMSR) ships to be used for this deployment.
rts=N	Limit aircraft to those needed for airlift in N round trips. The default is N=1 for air squadrons, 2 for airborne, and 1 to 7 for all other unit types, depending on size.
cmd=Name	(Re)Assign force to command "Name".

included in the deployment: outload via the port of New Orleans, transit to Korea via the Panama Canal, and enter Korea at the port of Pusan, then move administratively to its destination; move with eight days of supply; have the ships move together (as a convoy) between the seaport of embarkation (SPOE) and SPOD; to avoid causing any disruption at these ports, have no more than two ships loading or unloading at one time; and, finally, assign the brigade as a theater reserve to the command CFCK (Combined Forces Command, Korea).

The Deploy order to accomplish this (in the real command, the enclosed comments at the end of each line are dropped) is of the following form:

```
order US deploy 1-CAV/1-ARMB                     <order stem fields>
  rail>NewOrleans>sealift>Pusan>admin>Taegu      <destination field>
  czone/dos=8/convoy/eber=2/dber=2/cmd=CFCK      <mode field>
```

Complete instructions for the Deploy order can be viewed on-line in a Force window by typing "document orders deploy".

Route Orders

The Route order, which was in test and evaluation as of RSAS 4.6, has been fully implemented and is now the *only* way to order movement of specific naval *forces* (naval ships and/or task groups). A Route order can be issued to a single naval ship, to an explicitly named list of ships, or to all (or just the collocated) ships of a task group. It can thus have the effect of simply moving an existing contingent to another position, or of causing ships at widely diverse locations to rendezvous and then proceed together. So, whereas the Deploy order has one very complex destination and mode field, the Route order has a parameters (mode) field followed by a sequence of up to 20 route-specification fields, each of which can be mildly complex.

The *ships-affected field* (a prompt in the Route order) is tricky in some circumstances. Simply listing the ships to be routed (separated by slashes) can avoid confusion. For example, "Nimitz/Smith/Hall" implies that only those three ships are to be affected by the order. But when only one name (group, flagship name, or ship name) is specified, the "fineness" of the selection of ships can be indicated by prepending the name with one or two sharps ("#"); more sharps means "finer resolution" (fewer ships affected). Using a group name (e.g., CBG.6) or flagship name (e.g., Nimitz) means "the flagship of the named group **plus** all subordinate ships, including subordinate flagships and their subordinates." Prepending the name with one sharp (e.g., #Nimitz) means "the named ship and all ships in the same group that are collocated with the named ship." Note here that *collocated* does not mean exactly the same position—it means either in the same sea **region** if at sea, or the same land **region** if in port, at the time the order is given. Finally, two sharps means "the named ship only" (e.g., ##Nimitz means "just the Nimitz").

The *parameters field* (if used) contains guidance that is independent of specific legs of the movement. It defines departure time and/or guidance regarding restricted maritime passages:

- Departure Time: This can be expressed as an FTG or a DTG and must obviously be a time in the game future. If, for any reason, any ship affected by the order cannot be ready to sail by the explicitly stated departure time, the order is rejected (and the reason given). *Default*: If no departure time is stated, each ship affected will sail at the earliest possible time it can be made ready.
- Maritime Passages: If the *field* contains the guidance "suez", "czone", and/or "pole", any leg of the movement is authorized a transit of the named passage if all the ships affected by the order can comply. Only selected submarine classes can transit the Arctic (pole), and certain aircraft carriers are incapable of transiting the Suez and Panama Canals. *Default*: The government's current general policy about use of Suez and Panama Canals is applied, and Arctic transits are avoided.

Each *route-specification field* contains a destination position and an optional speed or arrival time. Table 7.4 explains the syntax and meaning of all allowable naval destination positions. Recall that Section 3 describes the JICM methodologies for simulating the routing of ships within and between major ocean areas (sea-beds), ports, sea regions, and seaboxes.

An *arrival time* is either an FTG or a DTG, and a *speed* is simply a number appended by "knots". When used, the arrival time or speed (but not both) is appended to the destination by an "at" symbol ("@"). For example:

- gigap/10@day15,0800Z means proceed next to seabox gigap/10 at whatever speed is needed to arrive exactly at game day 15 at time 0800 GMT.

Table 7.4

JICM 1.0 Naval Position Syntax

Type Position	Example	Meaning When Type Used
Land **Region**	US-West	Dock at the default seaport in this region as defined in file place.unc.
Place	Norfolk	Dock at this seaport place (it must be a port).
Sea **Region**	W-Med	Go to the geometric centroid of the named region.
Seabox	W-Med/8	Go to the centroid of the named seabox as defined in file maritime.unc.
Lat-lon	W-Med>37.2N8.4E	Go to the stated position (it is in degrees and fractions of degrees, *not* in degrees and minutes).

- gigap/10@18knots means proceed next to seabox gigap/10 at exactly 18 knots.

If any naval ship affected by an order cannot comply with any specified arrival time or speed, the order is rejected (for all ships that would have been affected) and the reason for rejection is logged. Since the Route order allows such complex movements to be ordered, a way has been provided that enables the feasibility of orders to be tested without actually issuing them. See the "display route" option at the Force window, and the on-line documentation for this display (which contains an example of every possible Force "ERROR" message stating the reason a Route order might fail, and what that message means).

Since each route specification applies to all ships affected by the Route order, the first occurrence of an arrival time in the order is clearly a point at which all affected ships will rendezvous if they are not already collocated. Once ships affected by the same Route order become collocated (including those that started off that way), they will move as a contingent for the duration of the move. Rendezvous will occur even for ships affected by different Route orders, so long as those orders specify identical rendezvous places and times, and movement will thereafter be as a contingent if the subsequent route specifications were also identical. It is thus possible to use several Route orders to cause a number of ships to rendezvous, then proceed together to a destination region or seabox, then diverge to different ultimate-destination positions.

The Route order normally is terminated with the string "end" (recall the syntax loops over an indeterminate number of route specifications). However, to record the details of what actions various ships will take as a result of the order, the order can be terminated with the string "report", which causes the same display to be logged as though the "display route" option mentioned above had been used.

Example of a Route Order

The following is a complete example of a Route order. Suppose the *New Jersey* and four ships of its subordinate contingent are operating in the Yellow Sea, and four other ships in a group led by the *Hall* are in the Japan Sea. Both groups are to cease operations at noon on game day 10; to assemble in the Korea Straits at noon on game day 12; then proceed to the port of Norfolk via the Panama Canal; and movement is to be at 15 knots once the ships are all together. This action can be done with the two Route orders that follow:

```
order US route #NewJersey      <order stem>
     Day10,1200Z               <implement time>
     KoreaStrait@Day12,1200Z   <rendezvous destination field>
     CanalZone@15Knots         <destination field>
     Norfolk@15Knots    end    <final destination field>
order US route #Hall           <order stem>
     Day10,1200Z               <implement time>
     KoreaStrait@Day12,1200Z   <rendezvous destination field>
     CanalZone@15Knots         <destination field>
     Norfolk@15Knots    end    <final destination field>
```

Complete instructions for the Route order can be viewed on-line in a Force window by typing "document orders route".

Logistics Modeling Changes

The Force model still has a number of auxiliary models to simulate logistics and support functions as they affect the military capability of forces. ITM has had major influence on these models. Also, since ITM has been in ongoing development, not all logistics models were converted to the new ITM framework and format in RSAS 5.0.[1] Most significant in this regard, the models that simulate the consumption and replenishment of ground force munitions were not completed until JICM 1.0.

Ground Force Modeling

The most significant logistics changes caused by the implementation of ITM are in two areas of ground force modeling. First, the resolution of weapons and equipment has increased significantly; many more weapons classes are represented, and preparations have been made to explicitly represent a number of supporting equipment classes. Second, the resolution of actual ground forces (i.e., named objects) has been standardized to division level, except where special conditions require otherwise.

Weapons and Equipment. Whereas the RSAS models collapsed all ground combat weapons into eight weapon classes, ground forces in JICM 1.0 have a total of 16 weapon classes. They are defined in Table 7.5. Also, for the first time, *personnel* (the number of combat troops in a unit) is recorded. Most of the force data in file ground.sec have been converted to this new format. Planned, but not yet implemented, is a capability to account for significant support

[1]RSAS 5.0 was the designation of a preliminary version of the JICM issued at the end of FY92.

Table 7.5

JICM 1.0 Ground Force Weapon Classes

JICM Class Name	Description of Weapons Included in Class
Tank	All tanks.
IFV	Anti-armor infantry fighting vehicles (IFVs) and armored personnel carriers (APCs).
APC	Other APCs.
Heavy-ARV	Other anti-armor armor.
Light-ARV	Other armor.
LR-ATW	Long-range anti-tank weapons.
SR-ATW	Short-range anti-tank weapons.
Mortar	Infantry indirect fire weapons.
Small-Arms	All other infantry weapons.
SP-Arty	Self-propelled (tracked) artillery.
TD-Arty	Towed (all other) artillery.
Gded-Adef	Radar homing air defense systems.
OIR-Adef	Optical/infrared homing air-defense systems.
Atk-Helo	Attack helicopters.
Other - 1 Other - 2	Special weapons to be explicitly represented, such as multiple rocket launchers (MRLs), ATACMS, other long-range artillery (LRA).

equipment classes, including organic transportation assets, such as trucks and utility helicopters.

Prepositioned materiel sets (POMCUS and MPS) and other war reserve materiel (WRM) also are represented at this expanded resolution of weapons. Such weapon stocks were previously treated as a type of "disabled" ground force. ITM provided the opportunity to convert POMCUS, MPS, and WRM into special types of simulation objects in their own right, and the data defining these ground materiel inventories are now in a new data file, materiel.sec. The Employ order is used to affiliate specific ground forces with either POMCUS or MPS sets. The Resupply order is still used to order the deployment of WRM to or between combat theaters. Models of weapons destruction, damage and repair, and WRM issue are already implemented in ITM. Damage and repair rates have been expanded from just one rate per theater side to one rate per ITM theater command per weapon class. WRM is still reserved for the forces of the government that owns it, but now also can be reserved for the forces assigned to specific commands. Use the "document orders" option in the Force window to see the on-line documentation for the Employ and Resupply orders. Use the "set materiel . . ." options to change weapon-class damage and repair parameters.

Divisional Resolution. The vast majority of ground forces are now accounted at division resolution (except for some independent brigades or regiments). Representing little change for many nations' forces (e.g., North and South Korean

forces were always at division resolution), it is a significant change for U.S. Army and other NATO units, which were at combat brigade or regiment resolution and separate combat service support brigade resolution before. Users wishing to carry RSAS 4.6 and prior scenarios into JICM 1.0 must adjust the force names to these changes and to the ground force name standardization mentioned in Section 1. In cases where components of a division must be deployed separately, the user may need to adjust the ground force data base. The data base has been modified to make it easy to create ground force units that are two brigades in size (see, for example, the U.S. 1-MXD or 3-ARMD). For example, if a scenario requires deployment of just one brigade of the U.S. 24-MXD (a division with three active brigades formerly called the "24-MECHD"), the data base could be modified to split this ground force into a one-brigade part and a two-brigade part. Even if the whole force is involved in a scenario, but its brigades need to be deployed separately, such a modification would be needed.

Munitions

There has been no change in the representation of munitions during the conversion to ITM. All munition characteristics and inventories are still defined in data files weapon.sec and weapon2.sec.

For ground munitions, the resolution is still "days of supply per equivalent division" for all Army weapons except attack helicopters (which are accounted as "flyable sorties") and long-range artillery (which is accounted on an individual-weapon basis). However, whereas older versions had only four consumption rates, JICM 1.0 has a separate ground force supply rate for each of over 20 mission postures (see the on-line documentation for MATERIEL->supply_rate for details and default values).

Air munitions are still explicit. Each air force (e.g., an F-15 squadron) has a primary aircraft authorization (PAA); more than 100 classes of aircraft (mission designator series, MDS) are defined in JICM 1.0. Various mission loads are described for each type of aircraft (in file air.sec) for explicitly represented munitions (see Table 7.6 for examples), and stocks of these munitions are positioned in land regions (and aboard naval forces), where they are subject to targeting and damage. Expenditures are per sortie flown, according to the prescribed mission loading or as ordered for specific strikes or strategic executions.

Missile forces include everything from intercontinental ballistic missiles (ICBMs) to mobile surface-to-surface missile (SSM) units, and inventories of missiles and

Table 7.6

JICM Air Munitions (Examples)

Munition	Description
Sparrow	Air-to-air missile
Maverick	Air-to-ground missile
Durandal	Airbase specialized attack munition
TAIR1	Air-delivered nuclear weapon
bullet	Nominal low-tech air-to-air munition
bomb	Nominal low-tech air-to-ground munition

munitions. Additional inventories of munitions (warheads) can be positioned in the same fashion as air munitions and are subject to targeting and damage.

For naval munitions, each naval ship has an inventory of weapons that can include ship-launched missiles, torpedoes, generic long-range and short-range air defense missiles, and aircraft-delivered weapons. They are expended during combat or are lost because of damage. Table 7.7 shows examples of naval munitions (other than aircraft-delivered weapons, which are the same as those shown in Table 7.6).

If support ships are associated with a task group, they will automatically replenish munitions expenditures or losses from combat ships on a first-come, first-served basis, up to the number of munitions on the support ship. Ships returning to port also receive replacement munitions up to their initial weapon loads, if resupply is available in the port's region that is owned by the ship's government. Ships in port also can be repaired if damaged. The ability of ports to replenish weapons and repair damage is degraded by damage to the ports inflicted by air or missile strikes.

Carriers and support ships carry a quantity of generic aircraft spare parts, measured in terms of the number of on-station days the spares will last. Expenditures by a carrier will be replenished by a support ship in the same task group; once the replenished parts are exhausted, alert rates of the carrier aircraft are degraded by a user-settable factor.

Facilities

Although a wide variety of types of support facilities are represented in JICM 1.0 for targeting purposes, only two types have a direct association with the ITM models: airbases and seaports. Each is described as an explicitly named object.

Table 7.7

JICM 1.0 Naval Weapons (Examples)

Munition	Description
Harpoon	Short-range antiship missile
TLAM-N	Sea-launched nuclear cruise missile
TASM	Conventional antiship missile
TORP	Default conventional torpedo for attack submarines
MK-46	Conventional torpedo used on surface ships
LRAAW	Generic long-range anti-air warfare missile salvos (2 missiles)
SRAAW	Generic short-range anti-air warfare missile salvos (2 missiles)

Seaports are defined indirectly in file place.unc, and airbases are defined in much detail in file airbase.sec.

Airbases. Each airbase is associated with a JICM place but is not necessarily at that place: It has its own positional representation (latitude and longitude to nearest hundredth of a degree). All airbases are now explicit objects (e.g., Hahn is a named base in FRG-West), although it is still possible to define aggregated bases in a region, if desired (but unlike before ITM, the aggregates must now be named and are located at the default place in the region). Airbase attack, damage, and repair models are essentially unchanged in ITM. However, as described in Section 5, targeting airbases and defining OCA plans are significantly easier under ITM than under either the CAMPAIGN-MT or CAMPAIGN-ALT models.

Seaports. ITM seaports are also at places, and each is assumed to include all the port facilities associated with the place. For example, since Los Angeles is a place in JICM 1.0, but Long Beach is not, Los Angeles must include all the port capacity in the area near it not explicitly modeled (including Long Beach harbor facilities). The aggregated port data formerly in facility.sec have been eliminated in favor of these explicit seaports, and aggregated data are generated dynamically in a manner similar to the treatment of explicit versus aggregated airbase data.

Lines of Communication (LOCs). Because the JICM now has a network model that covers all land regions, LOCs no longer need to be added as a separate element of the combat simulation models. They are an inherent property of the network. As of the JICM 1.0 release, the targeting models have been converted to allow air attacks to damage LOCs (using targeting code THTR_loc) along explicitly named arcs of the network. Also included have been the LOC damage, repair, and congestion models.

Targeting. As might be expected, the more-explicit-than-before representation of these facilities also permits a finer resolution of targeting. See the documentation for the Allocate order for details about targeting airbases (with OCA), and seaports and LOCs (with AI).

8. System Software Changes

Robert Weissler[1]

JICM 1.0 makes a number of changes to the system and support software. Some changes relate to the development of the ITM model and its use of the C-ABEL programming language. Others relate to use of the JICM within the X Window System environment of OpenWindows under Sun Operating System (SunOS) 4.1.3.[2] This section discusses these changes and describes transition issues relating to Sun system software upgrades and termination of support for outdated hardware platforms and software environments. Finally, we address the software initiatives planned by the JICM development team.

C-ABEL/RAND-ABEL Within the C Programming Environment

In the process of developing the ITM model, there was a desire to use the RAND-ABEL programming language for those portions of the model that were of direct interest to analysts, so that analysts would be able to read the adjudication tables and related code, but would also be able to modify those tables in a limited way to tailor the model to their needs. This subsection describes the C-ABEL implementation for ITM; how C-ABEL can be used to run RAND-ABEL control plans in stand-alone camper; how to recompile after making changes to the C-ABEL; how C-ABEL differs from its full-system counterpart; and the new language features that were added in FY92 that have supported work through FY93.

Implementation of ITM in C-ABEL

A major aspect of the design of ITM has been writing the key ITM adjudication procedures in C-ABEL. The decision to use C-ABEL required some development of the RAND-ABEL language and some changes in the JICM directory structure.

As part of the JICM Force-C models, C-ABEL code is found in the Force-C/Abel directory. Within this directory are further subdirectories:

[1]Barry Wilson and Mark Hoyer also assisted in this work.
[2]SunOS 4.1.1 was used with RSAS 5.0.

- Model—Code for ITM ground combat, ITM Ground Commander for manipulating forces within a command, and air combat.
- Plan—The control plan and any contingency functions.
- Dict—Data dictionary declarations of function names, enumerated types, and the structures used to interface to the C models.
- Obj—Where the C-ABEL object code is compiled.

The Model directory contains the following C-ABEL models. The data structures referred to are a new RAND-ABEL feature that is described later in this section.

LOC Commander (file commander.A). This model manages the frontal and reserve forces of a command in order to stay within terrain shoulder-space constraints, replace uncohesive units, and respond to insertions and flank attacks. It accepts the "LOCcmdr-struct" data structure, which contains a description of the command's situation and a list of its ground forces. It returns posture changes for those forces.

Ground Combat (files combat.A, sfs.A). This model fights opposing groups of ground forces, including the close combat between organized frontal forces of a command, combat between forces engaged on a flank, and rear-area combat with inserted or overrun forces. It takes two "Battle-struct" data structures describing the forces on each side and returns the losses and movement rates in the same structures. The file sfs.A contains tables implementing the Situational Force Scoring factors and ITM enhancements for terrain, battle, and combined-arms shortages.[3]

Air Commander (file ato.A). This model, run once at midnight for each command, takes the user's air Apportion and Allocate orders and produces an air tasking order (ATO) of aircraft packages for the entire day. Each package is assigned a specific target and time to fly. It accepts a single "Airplan-struct" data structure and returns a list of packages ("ATO-structs") in the same data structure.

Air Combat (file airwar.A). This model takes the combined ATOs of each side and adjudicates combat between attacking and defending packages and ground-to-air defenses.

[3]See Patrick D. Allen, *Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models*, RAND, N-3423-NA, 1992.

Control Plans

Within the C-ABEL environment set up for the ITM adjudication code, RAND-ABEL control plans can also be incorporated into the stand-alone camper program. Control plans that specify scenarios when placed in the JICM full-system INT (Interpreter) directory can be compiled into the camper program. Changes are required only to handle how variables are accessed, giving both the full-system and stand-alone camper modes of JICM operation access to the same scenarios.

The C-ABEL environment for control plans is as close to that of the full system as is possible. To compile an existing control plan into the camper program, simply move the file into the Force-C/ABEL/Plan directory and remove the file control-plan.A, which contains the default stub control plan. (A *stub plan* is an empty plan provided as a convenience to the user, who can then add instructions to it to define a desired scenario.) The file must end with the standard .A extension, and there must be one and only one control plan in the Plan directory at a time. When compiled in C-ABEL, the control plan does not have access to the global ABEL variables; it must operate either with local variables or with variables defined in the C code data structures.

Most of the RAND-ABEL global variables available to full-system control plans are not available in C-ABEL. However, macros are provided for two that are necessary, Next-move-time-limit and Move-done, simulating the corresponding RAND-ABEL variables. The macro facility of C-ABEL allows an apparent variable name declared in the data dictionary to generate specific C code. Thus, Next-move-time-limit, which sets the next hour the control plan will move, and Move-done, which allows moves to be marked off as they are done, are actually aliases for C code accessing variables kept in the camper program.

Other restrictions are that the control plan can only move on specified time increments—there is no Next-move-wakeup-function variable by which to post a wakeup function—and that the full range of force queries is not implemented.

In addition to standard control plans, users are able to specify C-ABEL functions containing orders to be executed within the 4-hour ground-combat-adjudication time step. When commands reach places where one axis splits into two or two combine into one, a major reorganization of forces may be called for. Using a control plan in the JICM full system means that orders can be issued only between the 4-hour time steps. But with this new feature, the orders in the specified *contingency function* (a function invoked from a call-plan instruction as described in Section 4) would be issued precisely when the triggering event

occurs. An example of the order syntax for specifying when a contingency function is to be executed is shown in Section 4.

Because they require some automatically generated support code, these order functions must be declared in the special data dictionary file Force-C/ABEL/Dict/contingency.D. Otherwise, they are declared as standard C-ABEL functions. The function code can be included in the control plan file or in any other .A file in the Plan directory. The Force model is notified of the name and conditions for execution of these functions through the call-plan script, found in the command parameter table. The C-ABEL support code for these functions is found in the file Model/contingency.A, which users should not modify.

Rebuilding the ITM C-ABEL Module

Initially, all source files are symbolic links to the master JICM system. When the C-ABEL code is to be changed, local copies of the appropriate files will be made, using the JICM *real script*, which changes a linked file to a real file in UNIX; after the changes have been made, the "make" command is run in the Force-C directory to incorporate the changes. The make process "enABELs" and compiles C-ABEL files and loads them, together with the C model object code provided in the C directory, to create a new camper binary in the Force-C/A directory. The previous camper binary is renamed ,camper; the user can remove it at his or her convenience.

Changes to any C-ABEL code file (ending in .A) will cause only the changed file to be remade. Changes to any data dictionary file (ending in .D) will cause all C-ABEL files to be remade.

If a new C-ABEL file has been added to either the Plan or Model directory, or an existing file has been renamed (or removed for some reason), then an additional step must be performed before the make in the Force-C directory. From the Force-C/Abel/Obj directory, enter "make clean" to remove all object files and make new symbolic links to the C-ABEL files.

Differences Between C-ABEL and Full-System RAND-ABEL

Because C-ABEL code is translated simply to normal C language code that is subsequently compiled as any other C module, C-ABEL is part of the C run-time environment. As a result, C-ABEL code integrates easily with existing C code such as that in camper. By contrast, full-system RAND-ABEL code is compiled

into a special run-time environment of its own that supports such features as the Interpreter, Data Dictionary, and coprocessing. In particular, without the Data Dictionary's being available at run time, it is not possible to interpret code on the fly. All changes to C-ABEL code must be compiled into a new executable (binary) file, resulting in a longer turnaround time for model changes. This slowing provides obvious motivation for integrating the Interpreter into camper. We discuss this proposed activity under "Future Directions" below.

Because the RAND-ABEL run-time environment references data through the Data Dictionary, RAND-ABEL data are kept and managed in special portions of memory for fixed and dynamic data. Special macros are required to access these data, whereas C-ABEL data are referenced directly by their (translated) C variable names. This kind of information should be needed only by programmers developing new interfaces between C and RAND-ABEL code or debugging such code.

New Language Features

After several years of experience with the RAND-ABEL programming language, it became apparent that RAND-ABEL lacked some important features available in C and other modern programming languages. Such features as structures and type unions make it possible to implement more-efficient storage structures, such as queues, stacks, hierarchies, and linked lists, whereas RAND-ABEL was limited to (often sparse) arrays. For this reason, such features were added to the RAND-ABEL language.

ABEL *structures* are composite data types consisting of a set of fundamental data types, such as integers, real numbers, and strings. When the structure is defined, it and all its constituent types are assigned names. For example, here is a sample structure definition (ABEL keywords [i.e., words with specific functions] are in **bold**).

```
Define Structure Type-unit:
        field1: 1.
        field2: 10.0.
        enum: Type-unit-name.
        nextfield: Pointer to Type-unit.
End.
```

After such structures are defined, variables can be declared as having that type. In the process, a record is created with fields having names and types as given in the structure definition. An example of such a declaration is

```
Declare This-GF-type: Let This-GF-type be Type-unit.
```

The fields or members of a structure can be referenced by the same ownership syntax that has been used for variables owned by Red or Blue, that is, possessive syntax as in

```
Let This-GF-type's nextfield be pointer to Similar-type.
```

In this example, we see that one unit record can point to another record, establishing a linked list of such records. Clearly, it is also possible to establish more-complicated structures representing command hierarchies and other relationships that are inefficient to represent with arrays.

ABEL (type) unions are likewise analogous to their C counterparts. *Unions* allow a given datum to be referenced as any of several defined types, using names assigned by the programmer. Such referencing provides, for instance, a way to assign a number to an object, then use that number as though it were the address of the object as well. Unions are obviously also a language feature subject to abuse when used to get around otherwise reasonable type-checking restrictions. The syntax for defining a type union is

```
Define Union Type-rank: One of
         numerical-rank: 1.
         enum-rank: Type-rank-order.
End.
```

A variable of this type can be declared simply as

```
Declare Priority: Let Priority be Type-rank.
```

One of the alternative names for this variable's type can be used to specify the type in effect at that point in the program. For example, the code below sets priority to integer value 2 and later sets it to enumeration value Second:

```
Let Priority's numerical-rank be 2.
Let Priority's enum-rank be Second.
```

Finally, many C primitive data types have been added to RAND-ABEL so that data types and variables of those types used in existing camper code could be referenced and accessed by RAND-ABEL code. Those types are **char, short, int, long, float, double**, and **unsigned** variants of char, short, int, and long. These types can be used anywhere an existing RAND-ABEL type can be used—for example, in the structure definition below.

```
Define Structure GROUND-entry:
         nextgnd   : 1.
         prevgnd   : char.
         location  : unsigned_int.
         size      : short.
         css-size  : long.
End.
```

Camper/CMENT Invocation Simplified

To eliminate unexpected, sporadic termination of camper and its CMENT user interface, we changed the manner in which these programs are started. In particular, in both stand-alone camper and full-system runs, camper was started first. The camper program then invoked its user interface CMENT, and the two communicated via a program called listen. This approach was necessary in the early days of development but had become a burden in recent years because it was not robust. Now, CMENT is started first so that it can invoke camper as a command within a TTY (character-based) subwindow in CMENT. This procedure is analogous to the behavior of Shelltool firing up a command within its window. This change should prevent unwanted and unexpected termination associated with overflow of buffers in the listen program.

Capturing JICM Graphics

With the advent of less-expensive color Postscript-compatible printers, and word-processing and presentation graphics software, there are increasing demands for sophisticated graphics in color. As a result, there is an ever-increasing need for efficient processing of graphics and for reliable conversion between formats on different computer platforms.

One area of the JICM that has a particular need for such processing is the capturing of color graphics off the screen. Whereas a simple "screendump" command was once adequate for black-and-white images of the entire screen, greater demands now include the ability to use a point-and-click interface to select a particular window to capture, the desire to print these windows in minutes, not hours, and the ability to bring graphics over to the Mac to incorporate as figures in documents or in briefing charts.

JICM Tool Screendump Options

In JICM 1.0, there are still two built-in Screendump (printout of the contents of the screen) options: one that delivers the screen image directly to the printer and another that places the image in a file. However, the direct-printing option has been changed to use a program called xgrabsc for greater efficiency in printing the image. This program generates compressed Postscript that downloads quickly, yet can be processed reliably by any Postscript printer. The Screendump to file option has not been changed, so it still produces a raster file that can be downloaded to the Mac and incorporated into documents with a product called PICTure This (note that upgrading to PICTure This version 2.0 is recommended,

because it now handles color images properly and appears to be more reliable). Both options capture the entire screen only; where greater flexibility is desired, a separate program is recommended.

The xgrab Screen Capture Program

Although Sun's SnapShot tool (which will place into a file a complete screen image or a subset of that image—a single window or group of windows) has a friendly point-and-click graphical user interface offering flexibility in selecting regions of the screen, it does not generate efficient Postscript for spooling directly to the printer. It still could be used effectively to generate raster images to be converted with Picture This on the Mac; however, we suggest another tool that can handle all the different requirements equally efficiently: xgrab. On RAND machines, this program can be found in /usr/bin/X11/xgrab (it is the graphical user interface for the actual imaging engine in xgrabsc).

Printing Screen Images Directly from Suns

A number of options are available in xgrab for specifying the extent, format, orientation, and output destination for the image. The *extent* is one of either the entire screen, a particular window that the user clicks on, or a rectangular region that the user stretches as if with a rubber band. The default format is compressed Postscript, best for printing, but there are also xwd and xbm/xpm formats that are useful for exchange with the Mac. Color Postscript is optional and will print as gray-scale on a monochrome printer (useful for proofing before submitting to a color printer, since the materials there are more expensive). The *orientation* is portrait by default, but landscape is best when capturing images of the entire screen. Finally, the *output* from xgrab either can be written to a file or can be submitted to a print command. At RAND, the default print command is "printout"; at other sites it will be "lpr".

Incorporating JICM Graphics into Mac Documents

When transferring a file from a Sun or other UNIX workstation to a Mac or PC, care must be taken because of incompatibilities between these platforms. The simplest way to get a file from UNIX to the Mac at RAND is with AUFS (Apple UNIX File System). By selecting Appleshare in the chooser, picking a server, and choosing Guest access, the user will have access to files in his or her macfiles directory on UNIX (via the Finder) as with any files on the Mac itself. At sites that do not have AUFS available, binary transfers with Versaterm or FTP (file

transfer protocol) can be done instead. Once the file containing the image is on the Mac, Picture This can be used to convert the image to Mac PICT format for incorporation into Microsoft Word or PowerPoint.

Picture This can handle the Sun raster file, xwd, xbm/xpm, and still other formats; consequently, many possible kinds of graphics files can be transferred and converted. Once a format is chosen in Picture This, the user can choose the option to copy the image to the clipboard, then select Translate to convert the image. Once the image is translated to PICT format and available in the clipboard, it can be pasted into the document, using, for example, the Paste As Picture menu option in PowerPoint.

An alternate means for incorporating Sun X-based graphics into a Word or PowerPoint document on the Mac is via MacX. For those users who have MacX installed and a color monitor with sufficient resolution, it is possible to display X applications in a Mac window. MacX has a copy screen menu option that provides three ways to capture a screen image and copy it to the Mac clipboard: selecting a specific window, selecting the background to get the entire screen, or dragging a rectangle. From the clipboard, the graphic can be pasted into Word, PowerPoint, or other Mac application without having to go through a sometimes-clumsy conversion process. However, use of JICM in conjunction with MacX has not been tested, so we offer this suggestion to only experienced users of MacX. A description of MacX is beyond the scope of this document.

We recommend against conversion of the image directly to PICT on the Sun, because the user must then be careful to set the resource of the Sun file (e.g., with the File Fanatic from the Mac) before transmitting the file via AUFS. AUFS assumes that UNIX text files should have new lines converted to returns; so, if the resource is not set, the image file might have unwanted conversion applied to it. If the user employs a binary transfer mode with a program such as Mac FTP, such conversion can be avoided and the file will arrive intact on the Mac.

Note that it is likewise possible to incorporate graphics into similar documents on a PC under Microsoft Windows, but a description of the process is beyond the scope of this document.

Support Issues

As the computer industry moves ahead, the JICM has followed the changes imposed by the move to an open architecture for processing, as with the UNIX operating system on SPARCstations, and an open graphics standard like

the X Window System. Naturally, that means weaning ourselves from old, proprietary architectures and environments.

End of JICM Support on Sun-3

With JICM 1.0, support for JICM operations on a Sun-3 has been dropped. The Sun-3 is no longer sold by Sun, and the latest versions of SunOS—SunOS 4.1.3 and 5.3 (in Solaris 2.3)—do not provide support for Sun-3 clients or servers. So this elimination of Sun-3 support was inevitable. In the next subsection on future directions, we discuss JICM portability to other high-end workstations that support such open standards as UNIX (i.e., POSIX) and X.

End of JICM Support Under SunView

Whereas OpenWindows does provide support for running SunView software under compatibility with X, Sun will not provide the tools to further develop or maintain SunView programs in Solaris 2.1. In view of limited resources, we shifted development efforts on JICM from SunView to X; many JICM features now are not available via SunView, including JICM Tool and JICM Map. Moreover, SunView programs are not consistent with the OPEN LOOK Graphical User Interface and do not interoperate smoothly with X programs—for example, in handling cut and paste and "drag 'n' drop" (a feature that marks a portion of text and moves it to a new location entirely with the mouse—no keyboard is required). Finally, JICM graphics have been redesigned as native X applications, so all essential components of the JICM have been converted from SunView. For all these reasons, support for running this system under SunView is no longer cost-effective or practical, so it has been removed from JICM 1.0.

OpenWindows 3.0 and ToolTalk

JICM 1.0 has been developed under OpenWindows 3.0, including the XView toolkit for menus, buttons, etc., and the new ToolTalk package for supporting real-time communication between applications. Although there is a high degree of compatibility between OpenWindows 2.0 and 3.0, our use of new features in 3.0 precludes the use of JICM under 2.0, because those features will not be available in 2.0. Therefore, JICM 1.0 requires upgrading to the latest version of OpenWindows: release 3.0 (or higher).

Future Directions

The important themes for JICM development in recent years have been ease of use and adoption of standards. Issues for the future include portability of JICM across hardware platforms that support UNIX; consolidation of JICM software to make it smaller, simpler to use, and more portable; enhancements to RAND-ABEL; and phasing out of obsolete software.

Portability and UNIX

There are several reasons to focus on portability of the JICM. First, the ability to run the JICM on the most cost-competitive, high-performance platform will improve the turnaround time for analysis and the response for interactive users. For example, the current performance leader in mid-range workstations is Hewlett-Packard, so there is a strong desire to port software to that platform. In addition, Sun is in the process of migrating its users from earlier Berkeley-derived versions of SunOS to Solaris 2.3 which includes SunOS 5.3, a System V Release 4 (SVR4)–compliant version of UNIX. That transition is again an attempt to move the industry to a standard operating system. These factors drive the desire for portability across machines that implement an open architecture (i.e., those based on industry standards).

Since the transition from Solaris 1.1 and SunOS 4.1.x to Solaris 2.3 and SunOS 5.3 is a major upgrade involving conversion to SVR4, we do not plan to move to the new operating system soon. Instead, we await a stable, reliable version of the new SunOS that has demonstrated itself to be free of major bugs. Performance of Solaris 2 is still slower than that of Solaris 1.1. Moreover, support for symmetric multiprocessing, to be available in upcoming models of the SPARCStation 10—the most compelling reason to move to Solaris 2—will not be available in the first release. At RAND, we do not anticipate moving to Solaris 2 as the production operating system for at least one year. JICM 1.0 has been developed and tested under SunOS 4.1.3, so JICM users should remain at that operating system version for the foreseeable future.

The effect of the Solaris 2 transition on the JICM will be most noticeable in system software dealing with memory management, interprocess communication, and coprocesses. Most applications will require the conversion of only a few library calls to their SVR4 equivalent in order to complete a source-level port to Solaris 2.0. Memory management will require more change, but still at the level of system library calls. Interprocess communication will continue to work in the near term because Sun will support Berkeley socket-based communication on top

of TLI (Transport Layer Interface). We see Sun's ToolTalk as the replacement for socket-based communication, because it is part of their Project DOE (Distributed Objects Everywhere), which complies with the emerging CORBA (Common Object Request Broker Architecture) standard. More importantly, ToolTalk has been included in the COSE (Common Open System Environment) agreement adopted by such major UNIX vendors as Sun, HP, IBM, and, most recently, DEC. The goal of COSE is to promulgate a "unified" UNIX to compete with Windows NT.

Coprocesses, which are the part of the code that executes independently in a multiprocessor environment, depend mainly on the underlying machine architecture, i.e., SPARC, but there are still some potential problems in porting this support to Solaris 2. Differences in interrupt handling and process context could interfere with mechanisms for polling coprocesses and coprocess sleep-and-wake behavior, or the differences could simply imply a different size and layout of a stack frame. If significant change is required here, we do not want to recode until, at the earliest, the Threads Library is available in Solaris 2. More likely, however, we will not choose to reimplement coprocesses at all. Some of these decisions will be driven by JICM development plans and some by the features of the Anabel programming environment toward which we are moving.

In the early part of the transition, Sun has guaranteed that there will be binary compatibility for software developed under SunOS 4.1.x. However, we have heard that this compatibility is not perfect, and we cannot depend on it. Therefore, porting of software at the source code level is a requirement for the JICM before it is suitable for release under the Solaris 2 operating environment. Furthermore, even at present (August 1993), many software products have not been ported to Solaris 2 (e.g., FrameMaker and Island Office).

The current performance leader in the workstation market changes almost from day to day, creating a strong desire to port software such as the JICM to hardware platforms other than Suns (e.g., HP's 700 series). Many of these systems run with a System V derivative operating system, so many of the porting issues mentioned above in the Solaris 2 context apply here too. For example, HP 700 workstations use the HP-UX operating system. Eventually, many of these vendors may replace the different UNIX versions with OSF (close sibling to SVR4), but it is still hard to predict if and when this UNIX convergence will take place.

The most difficult porting issue is, not surprisingly, that of getting coprocesses to work on HP, IBM, DEC, or other machines. Because each of these vendors has its own hardware architecture and assembly language, coprocesses would be

implemented differently in each architecture. Fortunately, JICM 1.0 is not currently heavily dependent on this code. It is hoped that standard application libraries supporting multiple execution threads may provide a portable solution in the future.

As mentioned earlier in this section, object-based interapplication communication on various hardware platforms in coming years may use a standard interface like CORBA, which would allow us to port our ToolTalk code to other platforms that comply with CORBA.

Portability and the X Window System

Since JICM 1.0 runs under the X Window System, the only unresolved graphics porting issue is whether the XView point-and-click interfaces need to be converted to the Motif GUI (Graphical User Interface) and, if so, when. Sun has announced that it will adopt Motif as part of the COSE agreement; the OPEN LOOK and the XView toolkit, therefore, appear to be at a dead end. On the other hand, Sun has indicated that, whereas no new development will be pursued in XView beyond Solaris 2.2, the XView toolkit and applications developed with it will be supported indefinitely in future SunOS releases. As a result, there is no immediate need to port graphical user interfaces to Motif. Therefore, JICM will move gradually to a Motif environment.

Both XView and Motif are based on the X Window System, so XView applications, including JICM applications, will continue to function under Motif. The only issue with Motif in the near term is consistency in the point-and-click interface from the end-user perspective. The look and feel of OPEN LOOK applications, that is, the appearance of window frames, menus, and buttons and the behavior of the mouse, differ from those of Motif applications and the Motif Window Manager that presents the desktop to the user. However, those differences are mostly superficial, because all window systems present very similar screen management functions to the user in the form of menus and buttons. Getting around in Motif is not substantially different from using OpenWindows.

Consolidation of the JICM

To make the JICM smaller and cheaper to maintain and to make it simpler to use, we are considering a consolidation of the JICM environment if further JICM development is funded. The ITM model already goes a long way toward realizing these goals, but there are many areas where we can make further

progress. One is to retire less frequently used tools. Another area is to focus on a few central user interfaces from which to issue commands and request displays. Yet a third area is to switch to off-the-shelf software when possible to reduce maintenance costs and increase robustness of the JICM.

One key feature missing from C-ABEL is the Interpreter that is part of the full-system JICM. We plan to transition from RAND-ABEL to the object-oriented Anabel programming language (see "Transition to Object-Oriented Anabel Environment" below); the new Interpreter for Anabel will be a key component of that transition. As part of the consolidation, we will integrate the Anabel Interpreter into the camper module so that ITM and other model code in Anabel can be modified at run time, instead of requiring recompilation. We are just now investigating the feasibility of doing this integration because it will require merging the Anabel run-time environment currently under development with that of C.

Some tools that have fallen into disuse will be retired and their features either incorporated into existing interfaces or dropped for simplicity. Among these tools are many that were part of the so-called full-system JICM: the System Monitor, Control Panel, and Hierarchy Tool. The time-step process is already controlled by camper, so similar functions of the System Monitor can move to camper, instead. CMENT provides an interface for game control, so the features of the Control Panel largely duplicate those of CMENT. For reasons of portability, we do not plan to bring coprocesses along. We still have the Sun-dependent code if we need it, but we may want to revisit coprocesses when UNIX has toolkits for developing multi-threaded applications. At that time, we would be interested in the potential for concurrency offered by symmetric multiprocessing as well. The Graph Tool may be replaced with an off-the-shelf product to reduce maintenance costs.

By combining the Anabel Interpreter with camper in the *single binary approach,* a combining of the JICM-A and JICM-C into a single binary (executable) program, we will eliminate the often input/output (I/O)–intensive interface that existed between them as separate processes. We will also remove most of the dependence on the RAND Strategy Assessment Center (RSAC) Daemon. The RSAC Daemon is a low-level interprocess communication library that is often unreliable and expensive to maintain. With System V UNIX becoming available in the near future, portability is also a question: Vendor-supported toolkits exist that are polished, reliable, and easy to use and maintain (e.g., Sun's ToolTalk). Where there is any remaining need for the RSAC Daemon—as with the launching of graphics—we plan to replace it with ToolTalk. Emerging standards will be based on the new toolkits and protocols.

Transition to Object-Oriented Anabel Environment

The field of modeling and simulation is fertile ground for emerging object-oriented software development technology: Battlefield entities are, in fact, physical objects—e.g., weapon systems or aggregates of individual objects, such as brigades and divisions—each of which has its own behaviors or methods. At RAND, there is an initiative to develop an object-oriented simulation language and environment to facilitate model development, maintenance, and use by analysts. That initiative is called the *Anabel Environment*, an object-oriented language that is a successor to the RAND-ABEL language; in fact, the name is short for "An ABEL Successor." The language is designed to leverage off existing RAND-ABEL language strengths, e.g., its readability, its Interpreter, and its run-time support for simulation. The Anabel work is being conducted by a separate project at RAND, but there is significant interaction between JICM users and programmers and members of the Anabel team.

The Anabel language will build object-oriented features into RAND-ABEL while maintaining backward compatibility with RAND-ABEL syntax. In this way, existing programs will require little, if any, modification to compile and run in the new environment. The RAND-ABEL structure type is being generalized as the Anabel *class* with inheritance and data encapsulation. Likewise, the RAND-ABEL *table* statement is being generalized to allow user-defined table types. Operators such as plus and minus that have fixed semantics in RAND-ABEL can be *overloaded* in Anabel with semantics that vary according to the objects that are subjected to the operation. As with C++, constructor and destructor operations will support dynamic object creation with garbage collection to clean up objects no longer in use. Finally, additional looping constructs will be provided to support iteration over lists and other user-defined types, including multi-level Break and Next statements.

Beyond the built-in language features of Anabel, one of the most important aspects of the environment will be a class library with reusable code to support simulation. Among other library objects to be implemented are event queues and schedulers for discrete-event simulation, input/output objects such as streams and the TLC free reader, and matrices as mathematical objects. Since Anabel is viewed as more than just a language—as a modeling environment, rather—graphics tools will be designed to operate in conjunction with the models. MapView, already a part of the JICM, will be incorporated into the Anabel Environment from the beginning. In that way, our investment in vector graphics for MapView will be preserved in the new environment.

Phase-Out of Data Editor

Because of RAND's adoption of office-automation software on the Mac, including Microsoft Excel, we have found Excel taking over some of the roles for which the Data Editor had been designed originally. Moreover, the Data Editor has largely fallen into disuse because interpreted analyst control plans have provided a more flexible way to specify war plans and modify them on the fly during a simulation. In addition, the Data Editor still has a SunView–based user interface that would need to be ported to XView. In view of these considerations, we plan to phase out the Data Editor in a future JICM version rather than adapting it to the new Anabel Environment. We expect the Anabel development effort to provide a class browser and hooks for downloading data to Excel on the Mac or perhaps to a spreadsheet on the Sun.

9. Making the JICM Easier to Learn and to Use

Daniel Fox

The JICM is a highly evolved simulation system for military analysis and war gaming at the operational-strategic level. The goal of the JICM development effort has been to be responsive to the needs of a wide class of users; therefore, the JICM includes a substantial array of features and encompasses a variety of sophisticated concepts. The features enable the JICM results to be sensitive to differences in the interests of the users. In short, it has been designed to be highly flexible to suit the widest possible range of applications. Such flexibility results, in turn, in a degree of complexity due simply to the number of options that the JICM offers.

JICM version 1.0 reflects our emphasis on making the JICM easy to learn and to use, which has affected the overall design of the JICM, caused us to put increased emphasis on graphical tools, and resulted in our adding specific JICM features aimed at easing use of the system. This section provides a brief overview of some of the design features that RAND has incorporated into the JICM that, we believe, have made the JICM easy to learn and use. Graphics enhancements for JICM 1.0 have been described elsewhere[1] in detail and are only briefly mentioned here. Two specific features added to provide easier access to JICM functionality, the JICM Tool and the Display Tool, are described in some detail.

JICM Design for Ease of Use

A major feature of JICM 1.0 is the Integrated Theater Model (ITM), which is the implementation of air-land combat in the JICM. The ITM is intended to incorporate the best features of several earlier air-land combat models and to provide a basis for further enhancement of the JICM combat modeling. Another major goal of the ITM is to provide models closely paralleling the operational-strategic planning process. Thus, land combat modeling is focused around real-

[1]Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, RAND, MR-122-NA, 1993. An updated description of this graphics system as used in JICM 1.0 exists as an unpublished RAND draft.

world planning considerations, such as lines of communication (LOCs) and a flexible, hierarchical command structure.

Lines of communication are selected from an available network of places and links connecting those places, as illustrated in Figure 9.1. Provisions are made, of course, for the user to easily alter and extend the network. A notional LOC is illustrated in the heavy line in Figure 9.2. The JICM analyst identifies as many or

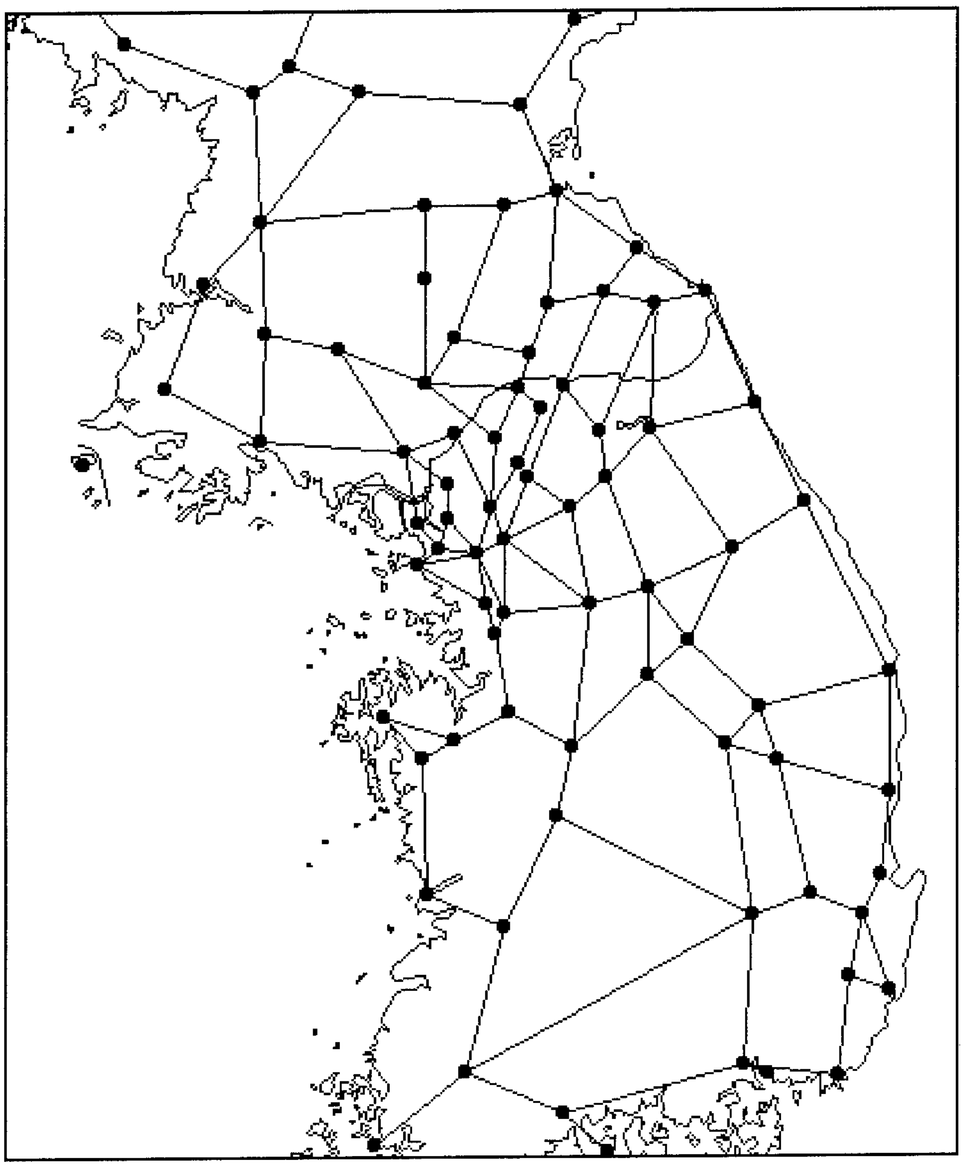

Figure 9.1—JICM ITM Places and Links

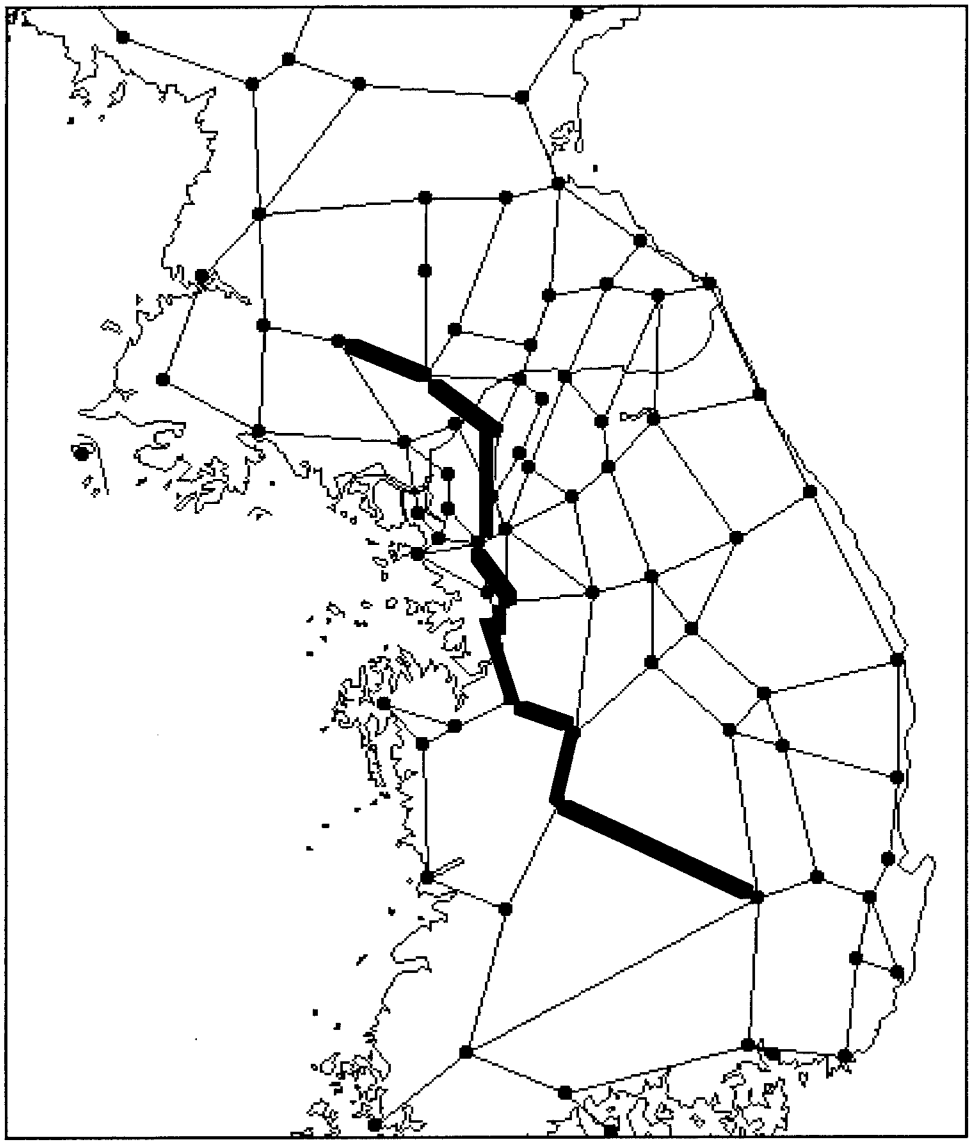

Figure 9.2—JICM ITM LOCs

as few LOCs as are required to represent the scheme of maneuver for a particular analysis.

Key to the representation of combat in the JICM ITM is the *command hierarchy*. A notional hierarchy is illustrated in Figure 9.3. The command structure can be nested to whatever depth the analyst finds useful in discriminating between the

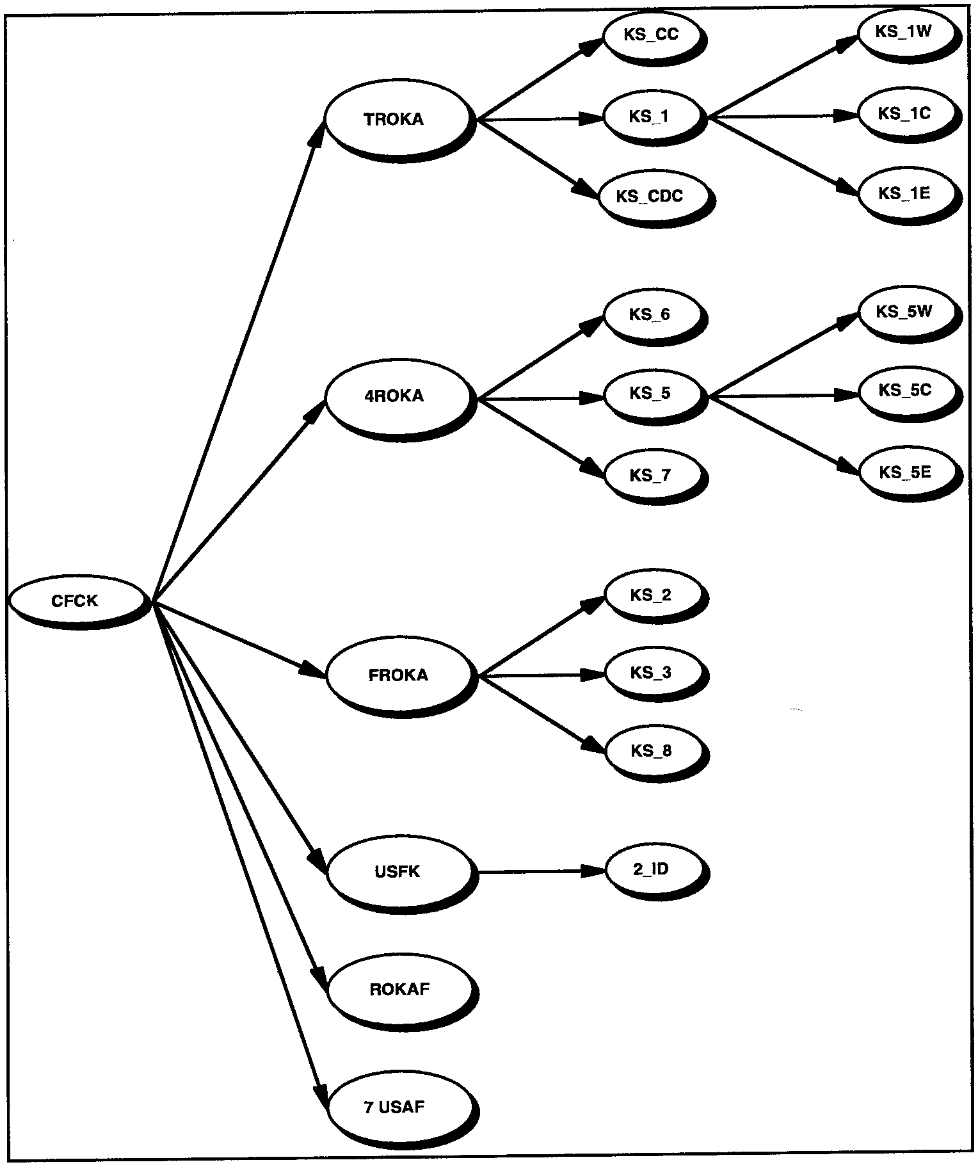

Figure 9.3—Command Hierarchy

functions of various forces; for ground forces, a separate ground command must be defined to operate on each LOC.

Ground forces assigned to various commands are deployed along the defined lines of communication. JICM Map displays these forces as in Figure 9.4. See Section 4 for more details on ground operations.

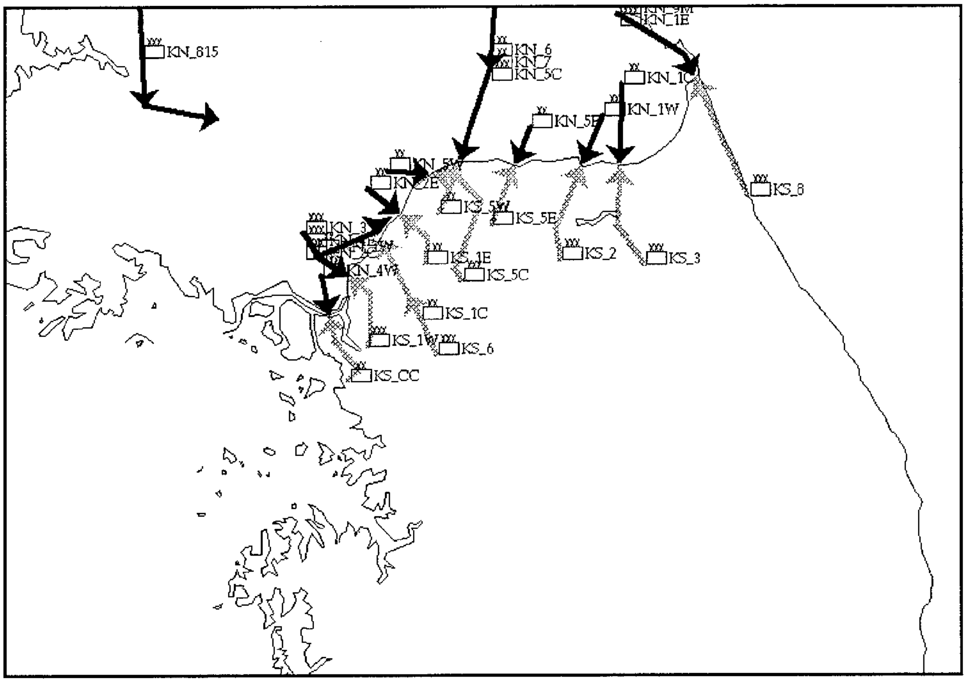

Figure 9.4—JICM Map Command Display

Air modeling is organized around a theater air tasking order (ATO) and, like the land war component, is based on a flexible, hierarchical command structure. The JICM analyst may define a command hierarchy (part of the hierarchy shown in Figure 9.3), such as that illustrated in Figure 9.5, to whatever detail is required. The theater ATO is automatically generated by the JICM, according to guidance provided by the analyst for the commands making up the theater. Each command may have separate guidance specifying allocation, apportionment, targeting, and timing. See Section 5 for more details on air operations.

New JICM Graphics

The new JICM Map graphics are tightly coupled with the JICM simulations. JICM 1.0 makes many of the simulation outputs available directly when the user selects icons on the graphics surface. In addition, certain placement information not otherwise readily available (e.g., distances between places along links in the network) can be easily obtained from the graphics.

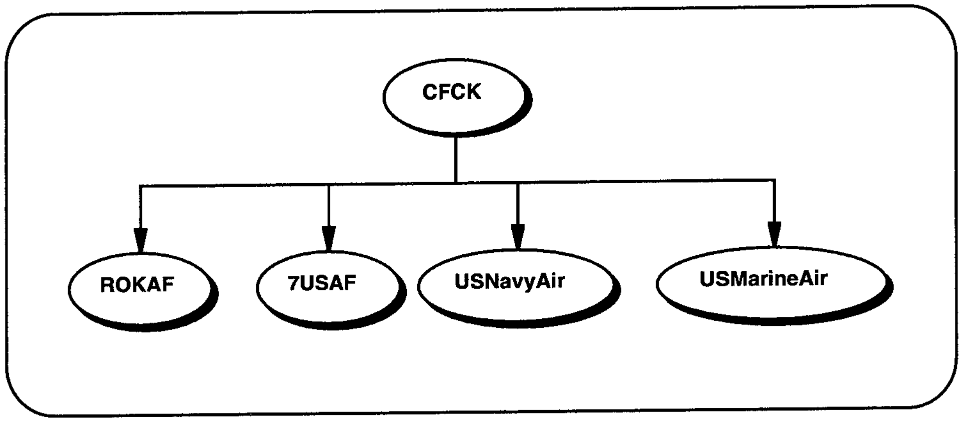

Figure 9.5—Command Hierarchy, Air Commands

We have a goal to make the graphics screen the primary interactive mechanism for the JICM simulations. We are actively pursuing logical designs to allow order input on the map-drawing surface.

The use of the JICM Tool to start the new graphics is illustrated later in this section. The functionality of the graphics is documented elsewhere[2] and will not be discussed further here.

JICM Features

Two special features of the JICM are presented in this subsection. The first, the JICM Tool, provides a convenient way to construct JICM user workspaces from available JICM-installed master versions and then select from available workspaces the particular JICM environment in which to run. In addition, the JICM Tool provides a single point of entry to the data files, source code, simulation outputs, and certain utility functions.

The second tool, the JICM Display Tool, provides a windows-oriented display capability that outputs displays at regular intervals over the course of the simulation but does not depend on individual requests for those displays. In effect, the Display Tool converts the "pull" display system, where the analyst halts the simulation and enters requests for the displays desired, into a windowed "push" system, where predesignated displays are output at regular intervals. The display outputs are, as usual, placed in the JICM log file. The

[2]Ibid.

Display Tool, however, provides an easy-to-use mechanism to access any of these displays without manually searching the log file.

The JICM Display Tool also can be used in a post-processing mode. For any JICM run made using the Display Tool, a stand-alone version of the Display Tool can be invoked that uses the same interface to provide access to the displays. Obviously, because the displays are stored in the log file, the post-processing mode can show only the displays that were selected for the Display Tool when the simulation was executed.

The subsections below illustrate the use of the JICM Tool and the Display Tool, presenting examples of the outputs.

JICM Tool

The JICM is installed in a master directory on a Sun computer or network. Users are not generally allowed to directly use the master installation; rather, to run the simulation, users create workspaces that parallel the master installation. This creation protects the master installation from inadvertent changes that could affect other JICM users. An analyst may have multiple JICM workspaces (also sometimes referred to as *JICM working directories*) associated with specific analytic or war gaming efforts.

The JICM Tool provides a centralized tool to perform a variety of functions, including the creation and management of those JICM workspaces. The JICM Tool not only provides a simple visual interface with which to select those JICM workspaces, but also invokes the graphic Display Tools and provides a single point of entry to data and source code files. Finally, the JICM Tool provides utility functions that allow, for example, the printing of text and graphic screen images.

The JICM Tool is invoked from the X Windows background menu. After logging in, start the X Windows environment by typing "openlook", then select JICM Tool from the background menu.[3] When the JICM Tool starts, a window similar to that shown in Figure 9.6 will appear on the screen.

Nine buttons are available on the JICM Tool. There are three different types of buttons, following standard OPEN LOOK conventions. Buttons that have a small inverted triangle on them, such as "Workspace Mgt" and "Utilities", offer

[3]Users not familiar with the X Windows environment and mouse-menu operations should see Daniel B. Fox, *Introduction to the JICM* (unpublished RAND draft).

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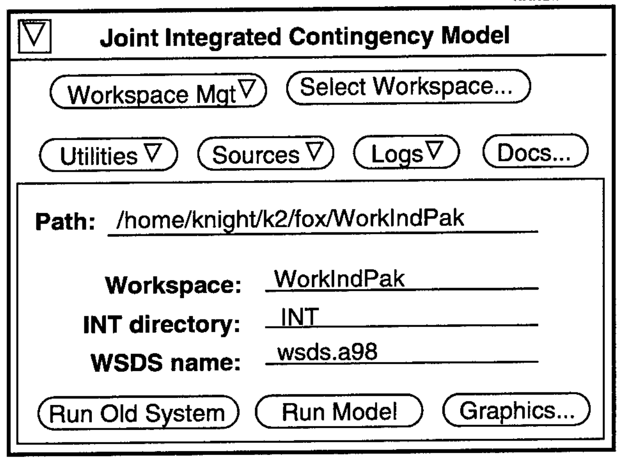

Figure 9.6—JICM Tool Window

pull-down menus when activated by moving the mouse cursor to the button and pressing and holding the right mouse button (RMB). Buttons that end with an ellipsis (...), such as "Select Workspace" and "Graphics", will cause another option window to pop up when selected with the left mouse button (LMB). Finally, buttons with no added marking, such as the "Run Old System" and "Run Model" buttons, will execute programs when the button is selected with the LMB.

From a functional viewpoint, the top two buttons ("Workspace Mgt" and "Select Workspace") are used to create and select workspaces in which to run the JICM. The bottom three buttons ("Run Old System", "Run Model", and "Graphics") are used to actually run the JICM and associated graphics tools. The middle four buttons ("Utilities", "Sources", "Logs", and "Docs") provide ancillary functions and convenient access to data, simulation output, and on-line documentation. The following paragraphs discuss the specific functions of each of the nine buttons on the JICM Tool.

The "Workspace Mgt" Button. Selecting the "Workspace Mgt" button with the RMB reveals the submenu illustrated in Figure 9.7. This submenu offers options to "Construct" a new JICM workspace, "Erase" an existing JICM workspace, or "Incorporate" a JICM workspace constructed without the aid of the JICM Tool into the set of workspaces known to the JICM Tool. Note that each of these three options ends with an ellipsis, indicating that selecting these options will cause a new option window to pop up. Also note that the "Construct" option is enclosed in an oval, which means that "Construct" is the default option and that if the

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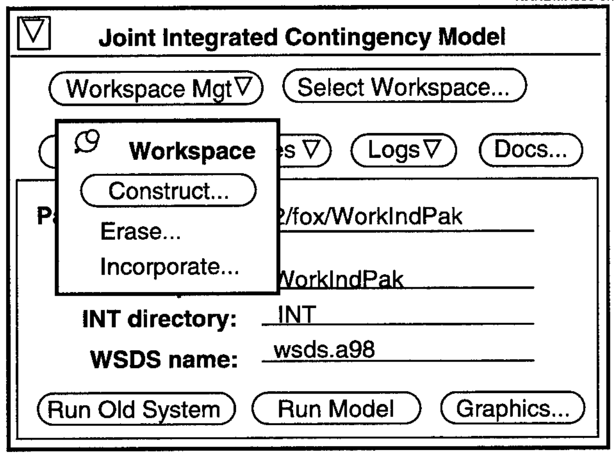

Figure 9.7—Workspace Management Pull-Down Menu

"Workspace Mgt" button is selected with the LMB, the "Construct" sub-option will be invoked.

The "Construct" Button. Selecting the "Construct" option under "Workspace Mgt" brings up the "Workspace Construct" option window illustrated in Figure 9.8. At the top of this window, the directory in which the new JICM workspace is to be created may be specified if write permission is given in the directory selected. The default here is the user's home directory. The next input is to identify the JICM master installation from which the workspace should be constructed. If the site has only one master version of the JICM installed, there will be only one choice available here. If the site has more than three master versions of the JICM installed, the scroll arrows to the right of the options will be active. Select one of the JICM master versions by using the LMB. On the next line, the JICM version selected will automatically be filled in with the path name of the selected JICM master installation. Two additional inputs are required from the user. On the "Create working directory" line, the default name for the workspace will be Work.

To create more than one workspace, the user must give each workspace a unique name. The JICM workspace can be given any name; however, it is standard procedure to have the name begin with Work. Finally, a long title may be entered. The purpose of the long title is to provide a memory jogger to help recall why this particular workspace was created.

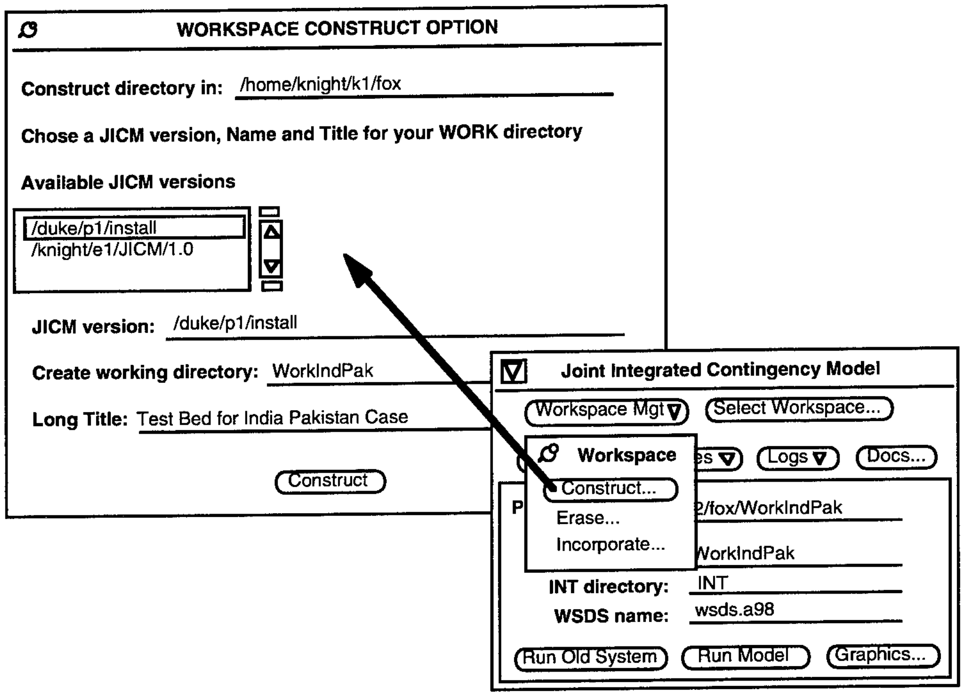

Figure 9.8—"Workspace Construct" Option Window

The "Erase" and "Incorporate" Buttons. The workspace "Erase" option is straightforward and will not be illustrated. It allows the user to identify and erase any previously constructed JICM working directory (both deleting the entry in the JICM Tool memory and removing the directory from the disk). Exercise care with this option. The workspace "incorporate" function is included to allow JICM workspaces constructed without the aid of the JICM Tool to be included in the list known to the JICM Tool. As long as the JICM Tool is used to construct JICM working directories, the user will not need this option.

The "Select Workspace" Button. After a JICM working directory is constructed, the next step in running the JICM is to select a workspace. This is done with the "Select Workspace" button. Activating this button with the LMB produces the option window illustrated in Figure 9.9.

At the top of the "Select Workspace" option window is a list of all available working directories. If more than three workspaces have been constructed, the scroll arrows on the right will be active. Any of the workspaces can be selected by using the LMB. When a JICM workspace is selected, the next four

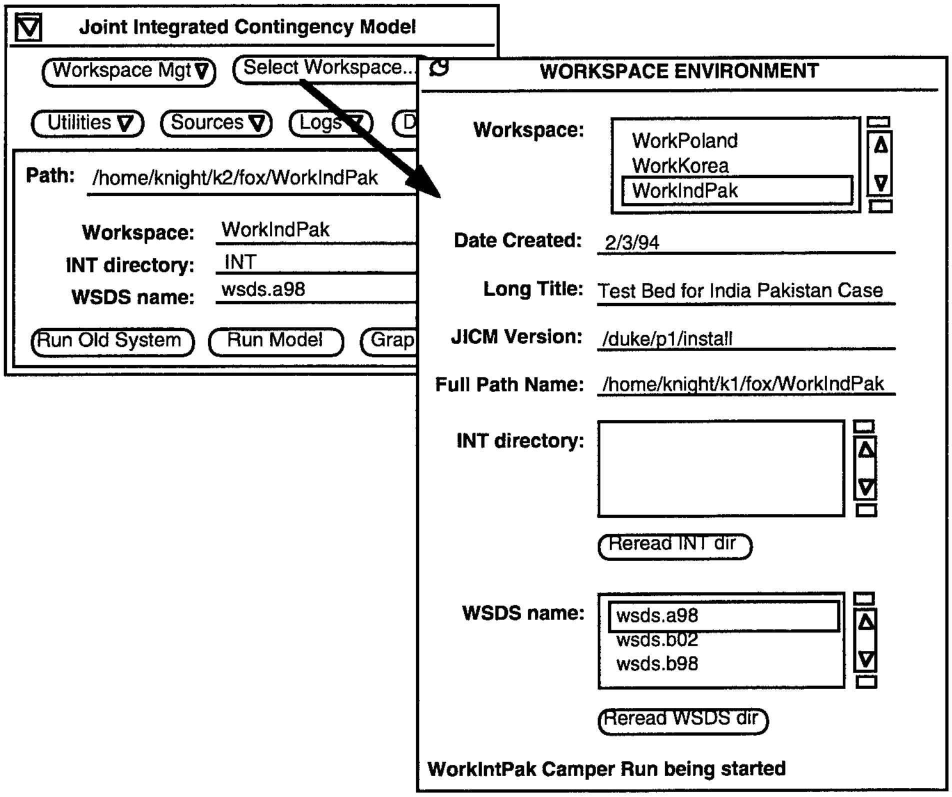

Figure 9.9—Invoking the "Select Workspace" Option Window

lines of information are filled in, including the date the working directory was created, the long title (memory jogger) the user entered when creating this workspace, the JICM version identified by the path name of the JICM master installation from which this workspace was constructed, and, finally, the full path name of this workspace.

Next, files in the INT directory (ABEL files that will be interpreted in a JICM full-system run) are listed. The ABEL Interpreter will interpret files with names that end with ".A" while ignoring others. Files in the INT directory with names that end with .A will show up with a box around them, indicating the active files. To change an active file (one that will be interpreted) to an inactive file (one that will be ignored), click on the file name using the LMB. The box around the file name will be removed, and, in the INT directory, the .A suffix will automatically be removed from that file name. Similarly, using the LMB on a file not currently active will cause a box to be put around that file name, and, in the INT directory,

an .A suffix will be appended to the file name. If the contents of the INT directory are altered (for example, by going to another window and copying files to or deleting files from the INT directory in the selected workspace), then selecting the button "Reread INT dir" will cause the JICM Tool to reexamine the file names in the INT directory and update the display to, for example, include new files.

Finally, near the bottom of the selected "Workspace" option menu is an opportunity to identify which World Situation Data Set (WSDS) should be used for this JICM run. The available WSDS files are shown, and one must be selected using the LMB. The selected file will be identified with a box around the name. If additional WSDS files are made available (for example, by going to another window and copying files or making new LINKS in the Wsds directory or running the input processor), activating the "Reread WSDS dir" button will incorporate these new file names in the list.

The "Run Old System" and "Run Model" Buttons. The last step in running the JICM after selecting a workspace is to activate either the "Run Old System" or "Run Model" button on the JICM Tool.[4] Figure 9.10 illustrates a CMENT and Force window running camper as a result of activating the "Run Model" button.

The "Graphics" Button. Selecting the "Graphics" button produces the pop-up window shown in Figure 9.11. On this window may be selected "Maps", "Graphs", or both before selecting "Start Graphics". Either the "Maps" or "Graphs" button is drawn with a shadowed border when selected.

Selecting the "Graphs" and the "Start Graphics" buttons results in a pop-up window for the application interface program (AIP) as illustrated in Figure 9.12. The source for the WSDS-C data should be the currently running server, which means that the camper currently executing will be used to obtain necessary data (so the user must start a camper run before proceeding beyond this point). The history data to be plotted will be read from the history file selected in the Graph Tool.

Selecting the "Continue" button will start the Graph Tool itself, the window for which is illustrated in Figure 9.13. From this point, use of the Graph Tool is unchanged from previous versions.

[4]The "Run Old System" button normally is not used. It invokes a more-complex environment that, in the current version, has little or no advantage over the more-streamlined operations illustrated here.

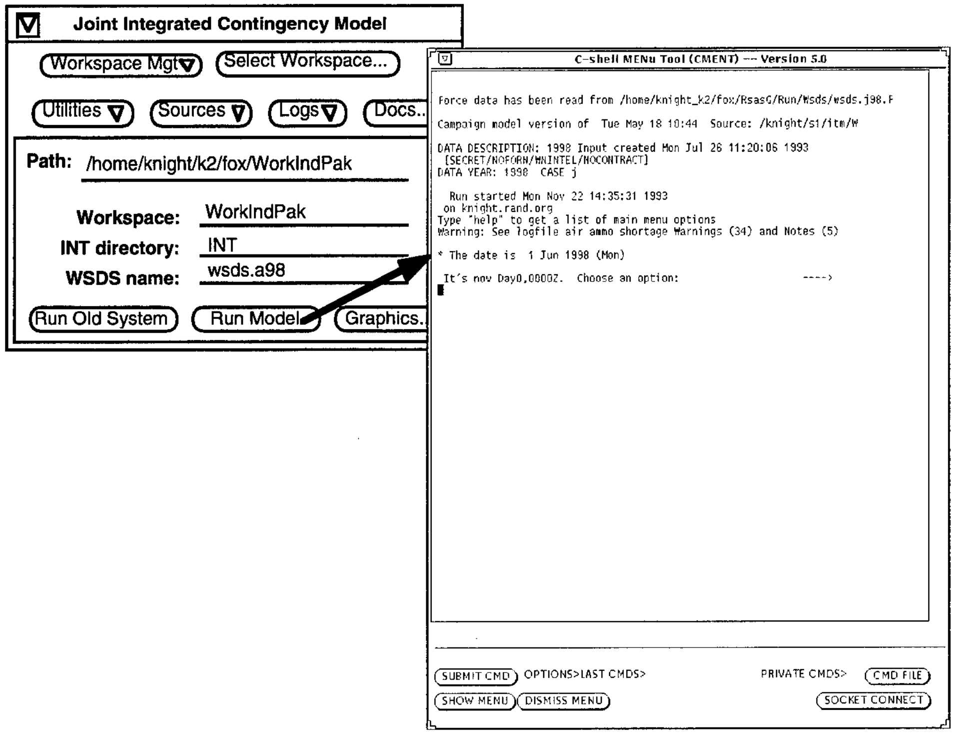

Figure 9.10—Invoking the JICM Simulation

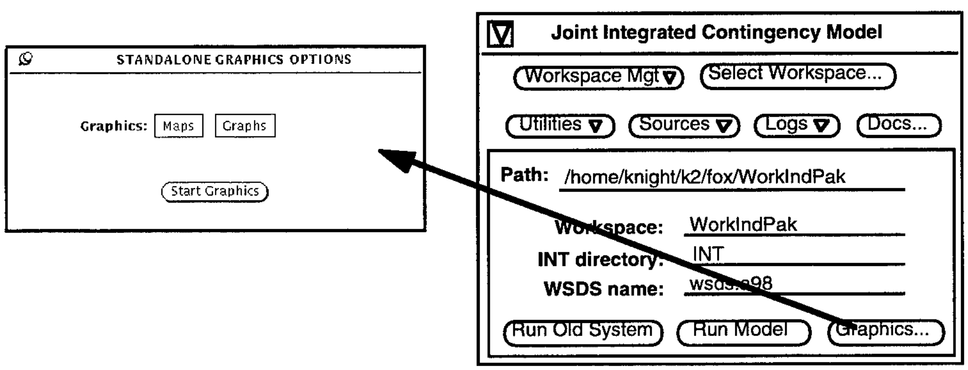

Figure 9.11—"Start Graphics" Menu

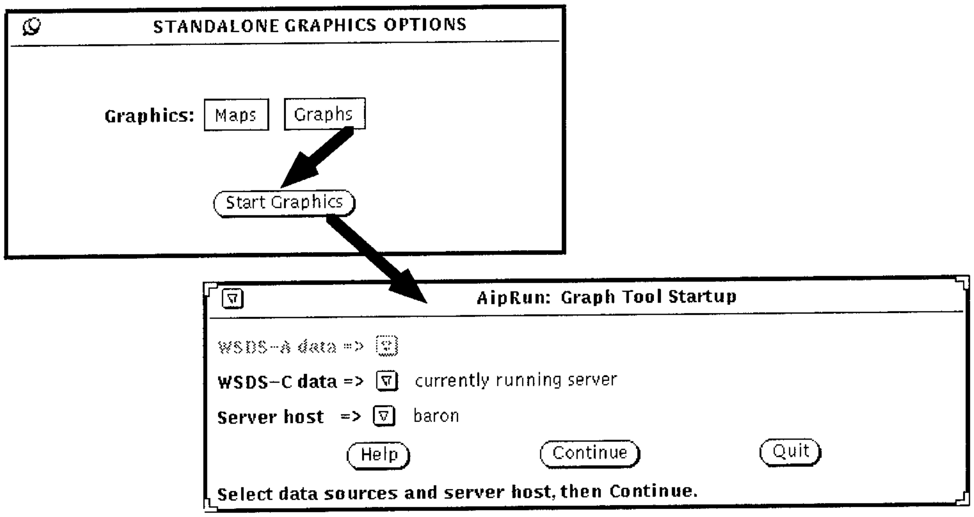

Figure 9.12—Application Interface Program Menu

Selecting "Maps" and "Start Graphics" on the "Graphics" option window produces the window illustrated in Figure 9.14.

Starting the JICM Map graphics is illustrated in Figure 9.15. Activating the ALL:"Start" button brings up the map server interface tool. Details on operating the JICM Map graphics are provided in another document[5] and will not be described here.

The "Utilities" Options. We turn now to the four middle buttons on the JICM Tool. Figure 9.16 illustrates the pull-down menu that appears by using the RMB on the "Utilities" button. The default option is "Screen Dump" (shown in the oval), which causes a copy of the screen to be sent to the printer. Recall that using the LMB on a pull-down menu selects the default option. It is easy for novice users unfamiliar with the X Window standards for use of the LMB and RMB to inadvertently send one or more screen dumps to the printer. The second option, "Screen Dump to file", saves a copy of the screen in raster image format to a file. This file can be converted to bit images and incorporated into word-processing documents (like this one). The "Remove Failed Run" option is intended for use after a hardware- or software-induced failure of the JICM to ensure that all processes associated with the failed JICM run are terminated before a new run is started. The "Bug Mail" option is a RAND internal

[5]Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, RAND, MR-122-NA, 1993. An updated description of this graphics system as used in JICM 1.0 exists as an unpublished RAND draft. See especially Section 3.

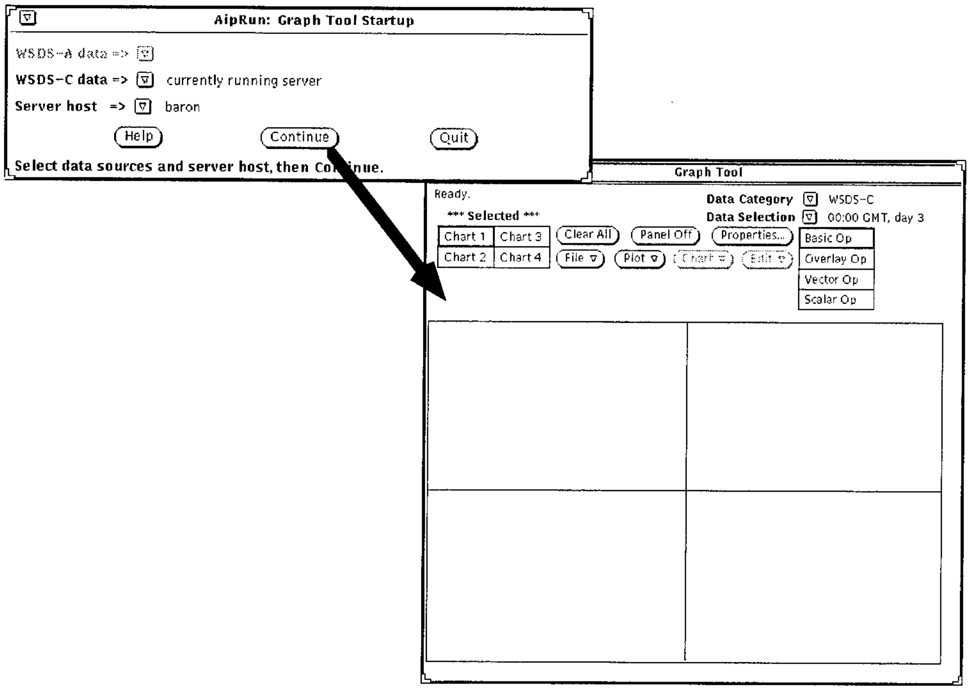

Figure 9.13—Graph Tool Window

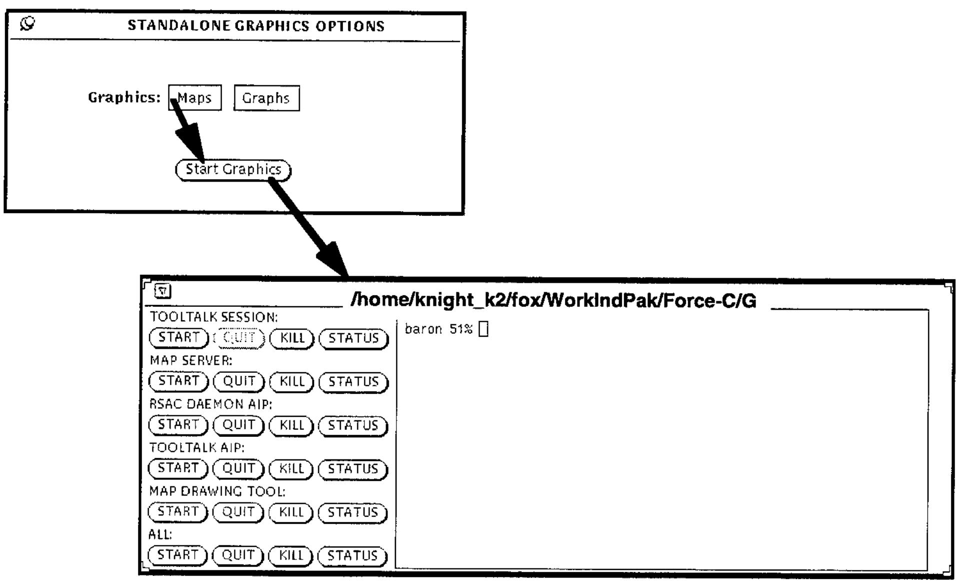

Figure 9.14—JICM Map Start-Up Window

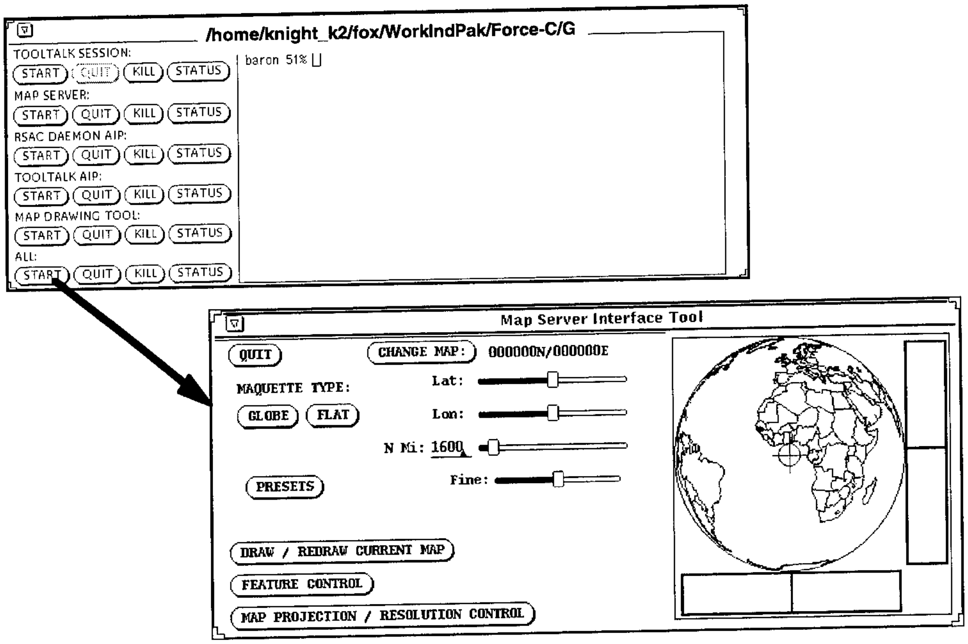

Figure 9.15—Map Server Menu

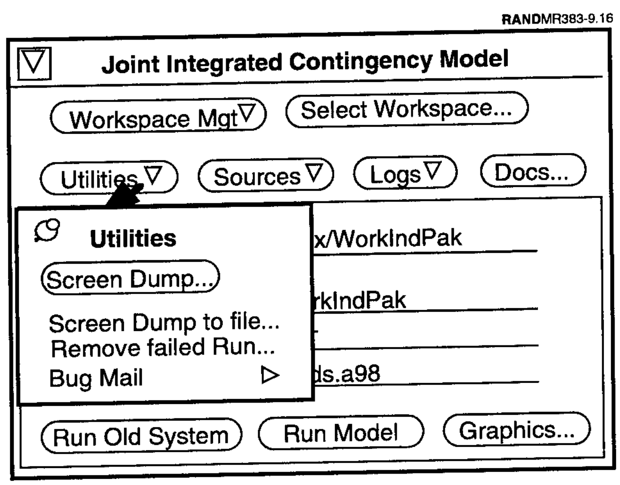

Figure 9.16—"Utilities" Pull-Down Menu

mechanism for reporting and tracking problems identified during testing. Few user systems are capable of employing this option.

The "Sources" Button. Figure 9.17 shows the options in the pull-down menu from the "Sources" button. This button provides access to the ABEL source code files and the Force-C data files. The third option provides access to the tableau files associated with the less frequently used JICM Data Editor.

The RMB may be used on the "Sources" button to access the Force-C/D file tool window shown in Figure 9.18. Activating the RMB in the Force-C/D file tool window produces a list of the data files in the Force-C/D directory. In a newly constructed JICM workspace, all these data files are symbolic links to the master JICM installation. To make local changes to the file, a local copy of that file must be made (the user is not generally given permission to change the master installed copy). If the data file selected is a link, then a pop-up window says, "The file is a link. Edit a copy of the real file?" If the user only wants to examine the contents, the response should be "no".

The "Logs" Button. Figure 9.19 shows the pull-down menu from the "Logs" button. Pulling right from the "Edit Logs" options produces the edit log menu. From here it is possible to access the ABEL logs (Command, Govt, Control, or Referee). Also accessible are the ,log and ,com output files from the current or most recent JICM run. The "Force-C Notes" option produces a summary of the number of Warnings, Notes, and Errors in the current ,log file. The "AWP Timeline" is not applicable until new Analytic War Plans are developed for ITM.

The "Docs" Button. Figure 9.20 illustrates the pull-down menu from the "Docs" (Documentation) button. The hierarchy of the menus replicates the directory and

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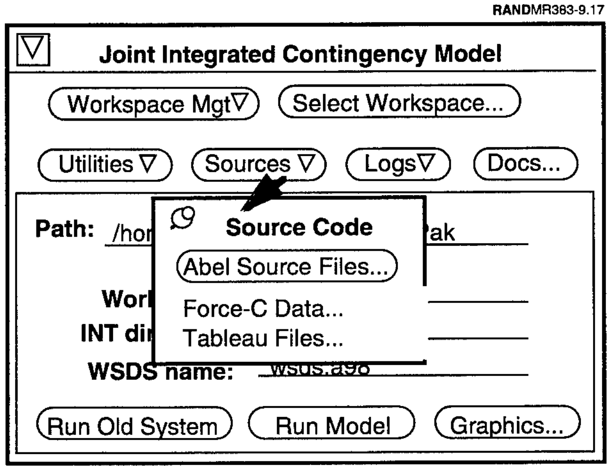

Figure 9.17—"Sources" Pull-Down Menu

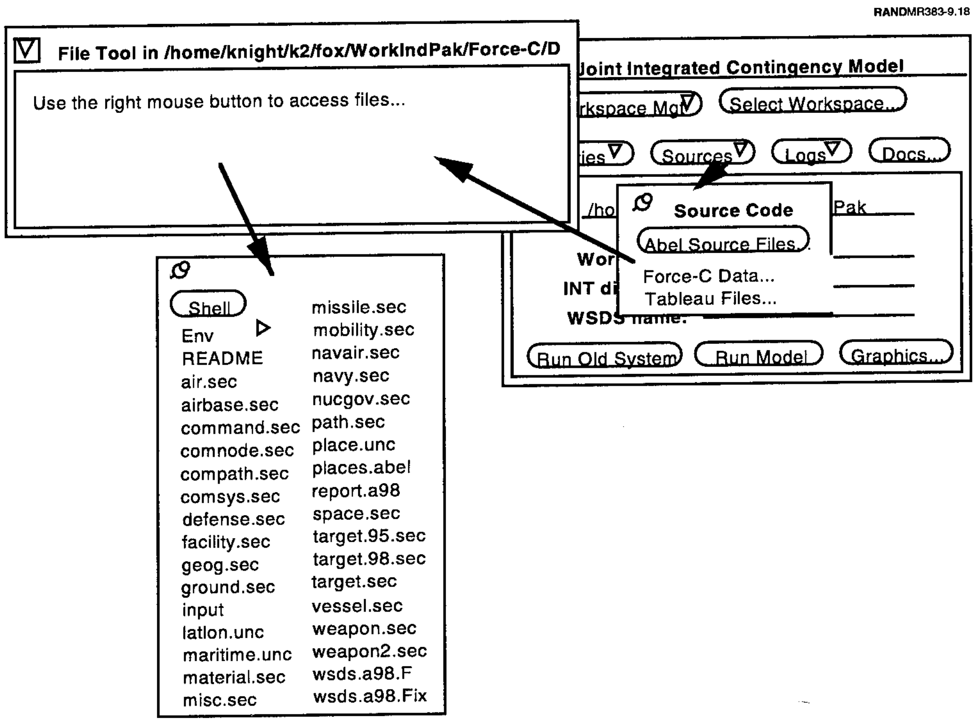

Figure 9.18—Force-C Data File Menu

file structure in the Doc directory. Selecting a file opens an editor window that displays the selected file.

JICM Display Tool

The JICM Display Tool provides a means to produce a set of JICM displays at regular intervals throughout the simulation run, and it affords convenient access to these displays both in the course of the simulation and, via a stand-alone option, in a post-processing mode.

The first step in using the Display Tool is to define the set of displays to be produced. The display orders are entered in a file named dtool.disp in the user's home directory. This file can contain many display sets. Each display-set definition begins with a greater-than symbol (">") followed by an identifying name for the display set. Following this name, one display command is entered per line; up to nine display commands can be entered exactly as they would be in

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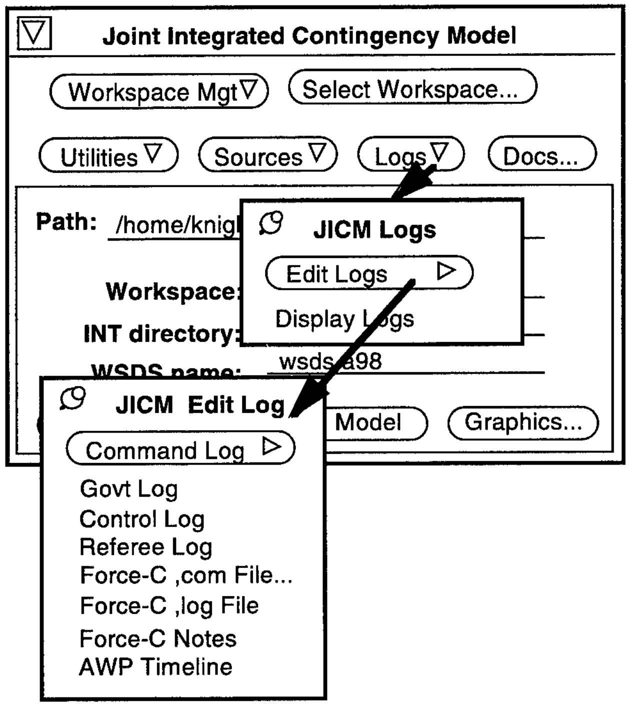

Figure 9.19—Edit Log Menu of "Logs" Button

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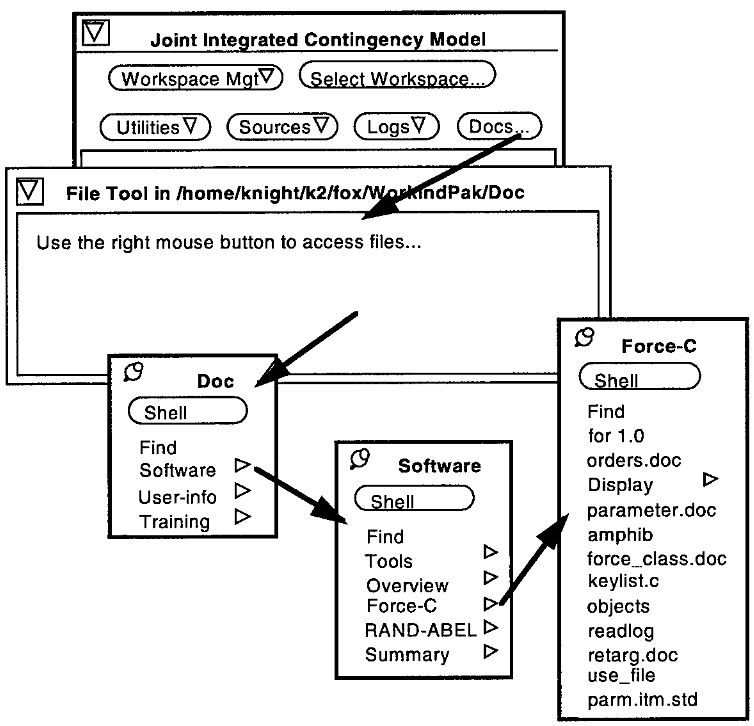


Figure 9.20—"Docs" (Documentation) Menu

the Force window (or in a use file). Figure 9.21 shows an *edit window* (a window running a full-screen editor with text in it) with a sample dtool.disp file defining several display sets. The first display set shown is named ITM.air and has seven displays. The next display set is named Korea and has nine displays. A third display set is named SEA DISPLAYS, and additional display sets are also visible in the edit window.

To use the Display Tool, start the JICM run in the normal way, using the "Run Model" button on the JICM Tool. At the bottom of the CMENT window, click with the LMB on the "Show Menu" button to produce the CMENT window as illustrated in Figure 9.22.

In the CMENT menu window, again use the LMB to click on the "Display Tool" button to produce the Display Tool window as illustrated in Figure 9.23. At the right side of the Display Tool window is a subwindow showing the available display sets. When using another window to change the dtool.disp file, click the LMB on the "REREAD LIST" button to get the current lists. If more than five

```
baron:/tmp_mnt/home/knight_k2/fox
+-------+-------+-------+-------+-------+-------+-------+-------+-------+-----+
|>ITM.air
|d cmd a cfck - -
|d cmd a dprk - -
|d itm-ai 7usaf
|d itm-at 7usaf all
|d dam indus main nkor end
|d hist-a 7usaf
|d battle air 7usaf
|>Korea
|d cmd g cfck - -
|d cmd g cfck - skor
|d cmd a cfck - -
|d cmd a cfck - skor
|d x cfck
|d z cfck2
|d z cfck4
|d misc cfck
|d sor cfck
|>SEA DISPLAYS
|d flag US total
|d flag EISENHOWER
|d navair all US US-SE all
|d patrol satlan
|d tas d2_Wlant d1_Barents end
|>IRAQ DISPLAYS
|d mob US
|d sland_sqdn Iraq
|d sland_gnd Saudi_Arabia
|d cm f ag-arabia - -
|d cm f fr-arabia - -
|>KOREA DISPLAYS
+----------------------------------------------------------------------+----+
                WP              At 1      in dtool.disp
```

Figure 9.21—Creating a Display Set

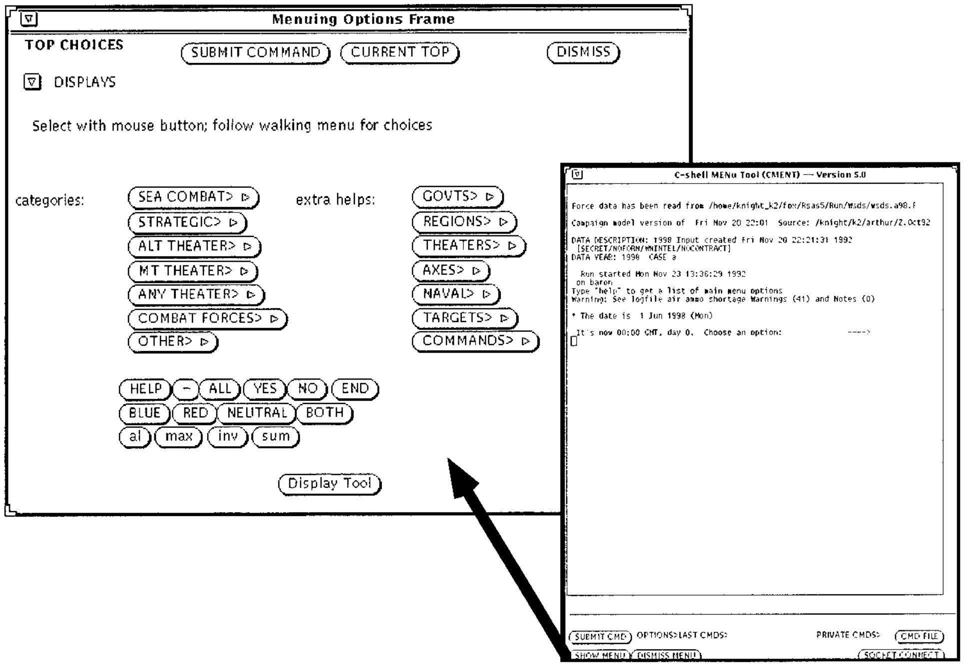


Figure 9.22—CMENT Menu

display sets have been defined, the scroll arrows on the right of this subwindow will be active. To select a list, click the LMB on the name of the list. Figure 9.24 illustrates the Display Tool window after the display set ITM.air has been selected. The interval at which the displays will be saved can be changed at the bottom of the window. The default interval is every 24 hours. Recall that the output of these displays is saved in the ,log file. Requesting many lengthy displays at frequent intervals can produce a very large ,log file (the RAND editor can read a file up to only about 32,000 lines in length; if the log file exceeds this length, working with it may be difficult [e.g., the file may have to be split into pieces so that it can be read or displayed in the editor]).

After selecting the desired display set, click on the "SUBMIT LIST" button using the LMB. As illustrated in Figure 9.25, doing so causes a number of messages to be transmitted to the simulation and displayed in the Force window.

At this point, the simulation can be run normally (i.e., interactively or with a use file or control plan). As illustrated in Figure 9.26, if one of the "OPEN" buttons on the Display Tool window is selected, a window will be opened, displaying the most recent version of the associated display. The "PREVIOUS" and "NEXT"

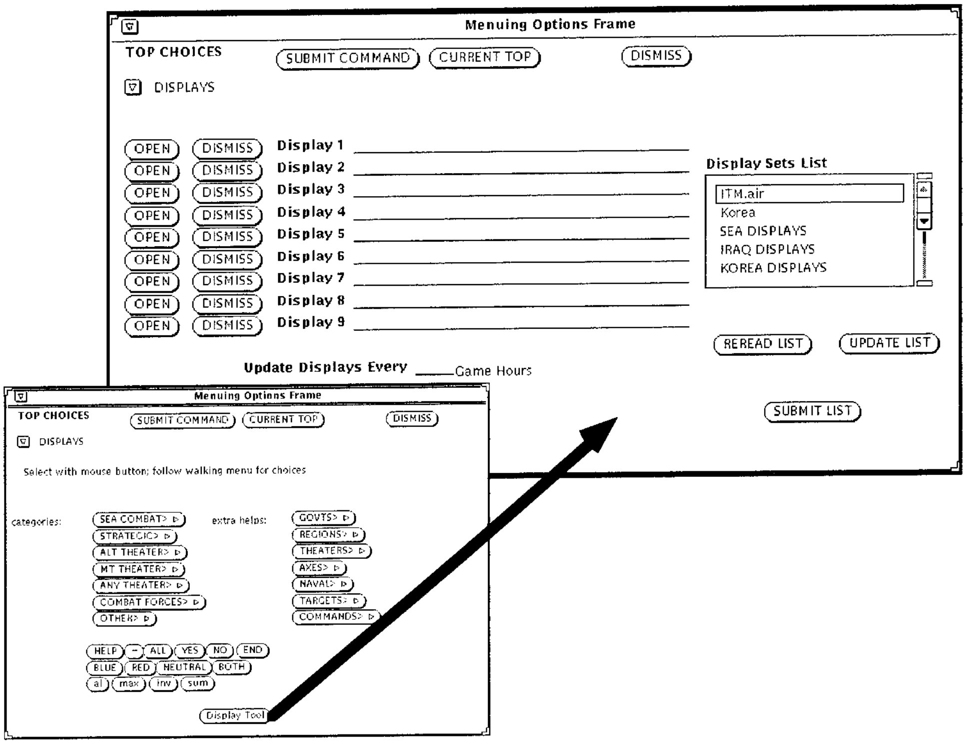


Figure 9.23—Display Tool Menu

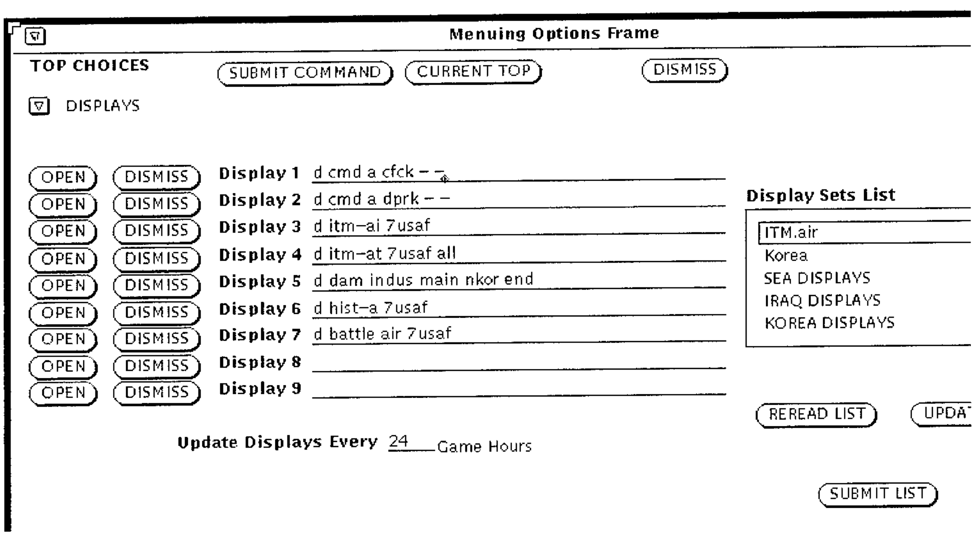


Figure 9.24—Selecting a Display Set

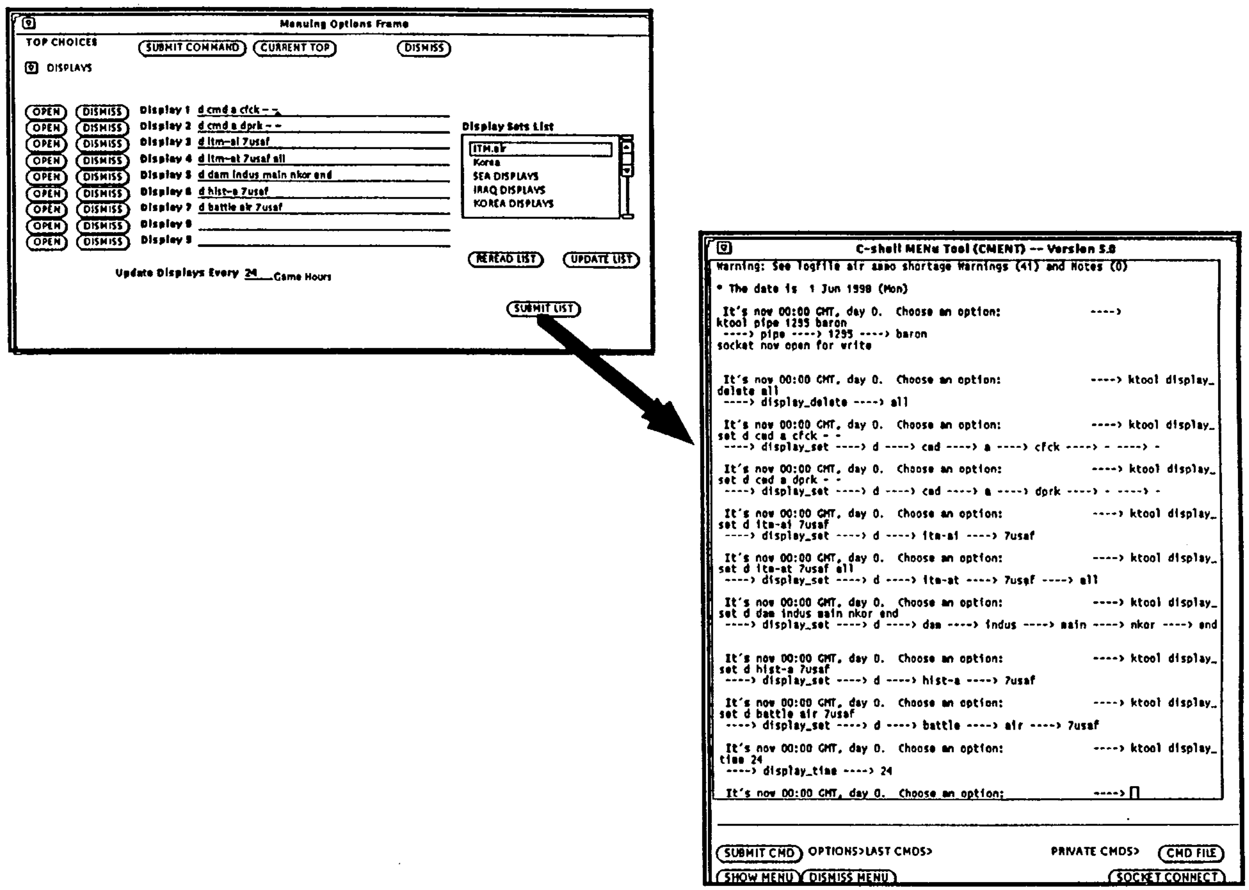


Figure 9.25—Submitting a Display Set to camper

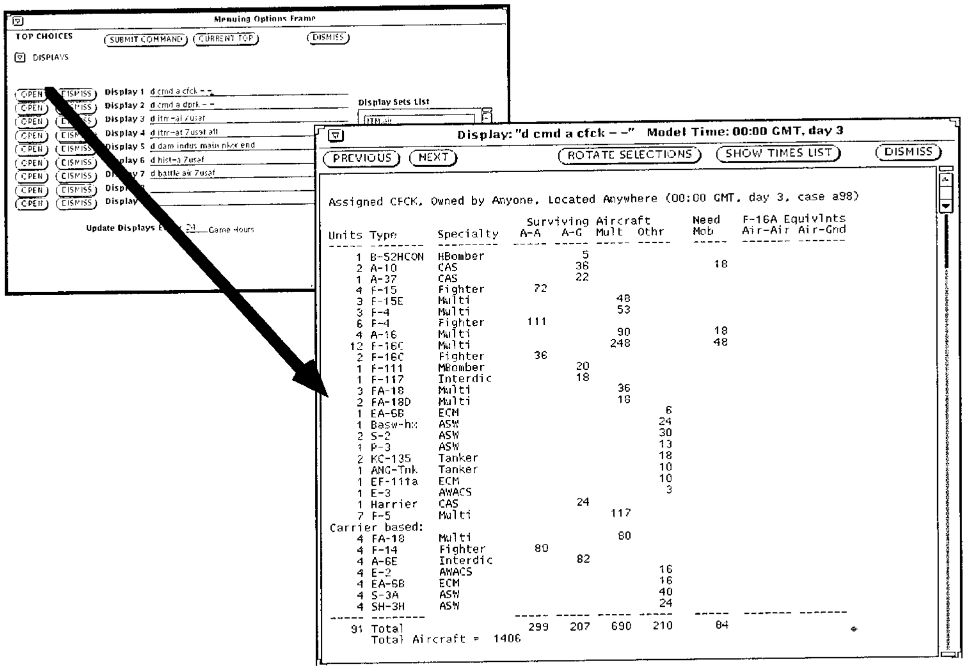
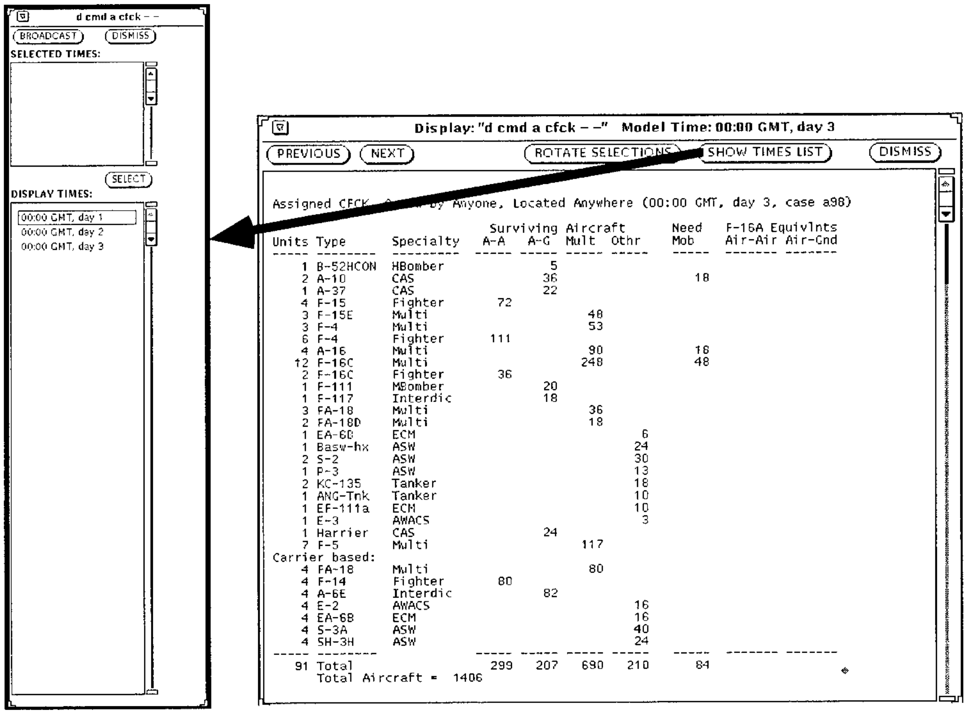


Figure 9.26—Display Tool Output

buttons near the upper-left-hand corner of this display window may be used to move to earlier or later versions of the display. Multiple windows may be opened and rearranged on the screen. If the windows are left open while the simulation proceeds, they will be automatically updated. Note that updating the windows involves substantial input/output overhead, and having many windows open can slow the simulation. There is little overhead, however, when the display windows are closed.

The "SHOW TIMES LIST" button allows immediate access to all display times. Illustrated in Figure 9.27 is the display times window. The lower of the two subwindows lists the time and day for which this display has been saved by the Display Tool. Clicking on any of these times using the LMB changes the display window to the display at that time and day. The "DISMISS" button on either the Display Tool window or the display window itself can be used to remove that window from the screen.

For any JICM run that has been made using the Display Tool, the same display functionality is offered for post-processing. To use this capability, ensure that the ,log file from the simulation run (in the Run/O directory) is saved. To save the ,log file, rename the file using a name not beginning with a comma to prevent the



Units	Type	Specialty	Surviving Aircraft A-A	A-G	Mult	Othr	Need Mob	F-16A Equivlnts Air-Air	Air-Gnd
1	B-52HCON	HBomber		5					
2	A-10	CAS		36			18		
1	A-37	CAS		22					
4	F-15	Fighter	72						
3	F-15E	Multi			48				
3	F-4	Multi			53				
6	F-4	Fighter	111						
4	A-16	Multi			90		16		
12	F-16C	Multi			248		48		
2	F-16C	Fighter	36						
1	F-111	MBomber		20					
1	F-117	Interdic		18					
3	FA-18	Multi			36				
2	FA-18D	Multi			18				
1	EA-6B	ECM				6			
1	Basw-hx	ASW				24			
2	S-2	ASW				30			
1	P-3	ASW				13			
2	KC-135	Tanker				18			
1	ANG-Tnk	Tanker				10			
1	EF-111a	ECM				10			
1	E-3	AWACS				3			
1	Harrier	CAS		24					
7	F-5	Multi			117				
Carrier based:									
4	FA-18	Multi			80				
4	F-14	Fighter	80						
4	A-6E	Interdic		82					
4	E-2	AWACS				16			
4	EA-6B	ECM				16			
4	S-3A	ASW				40			
4	SH-3H	ASW				24			
91	Total		299	207	690	210	84		
	Total Aircraft = 1406								

Figure 9.27—Display Tool Time List

file from being automatically deleted by the UNIX system. To invoke the post-processing Display Tool, open a shell tool to the Run directory in the workspace in which the simulation was run. Enter the UNIX command

```
dt O/filename
```

where filename is the name assigned to the ,log file for the original simulation run. This command will bring up the Display Tool window, illustrated in Figure 9.28, which operates the same as the Display Tool window used with the live simulation. From this window, display windows may be opened, and time lists may be displayed from them, as described previously.

RANDMR383-9.28

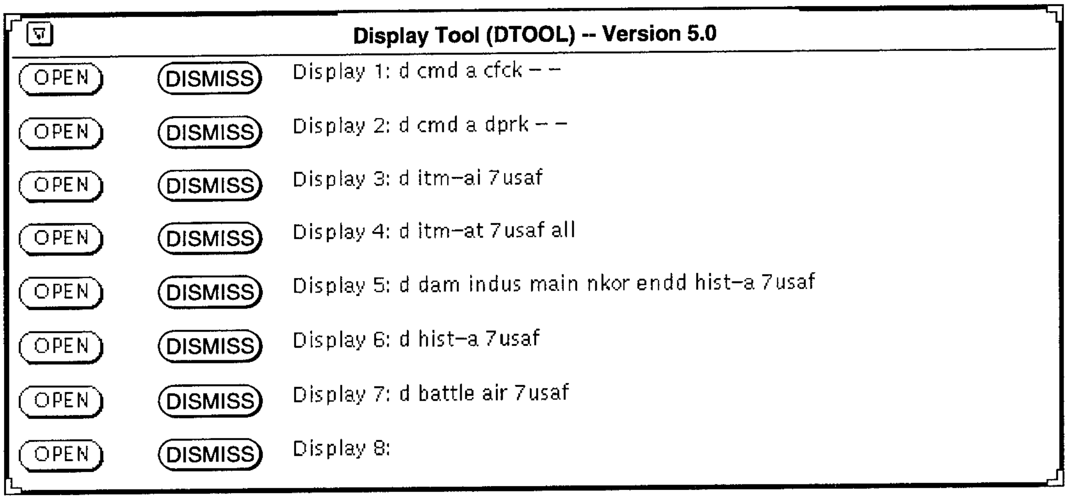


Figure 9.28—Post-Processing Display Tool

Appendix
A. JICM Reference Documents[1]

Besides the documents listed below, users are directed to the Doc directories of each JICM release for more complete and up-to-date documentation, especially on technical implementation.

JICM Overview

This document provides the best JICM overview. Historical descriptions of the RSAS and its objectives are found in:

- Paul K. Davis and James A. Winnefeld, *The RAND Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, RAND, R-2945-DNA, March 1983.
- Bruce W. Bennett et al., *RSAS 4.6 Summary*, RAND, N-3534-NA, 1992.

User or Reference Manuals

Only one formally published user manual exists:

- Bruce W. Bennett and Mark Hoyer, *The New Map Graphics in RSAS 5.0*, MR-122-NA, 1993.

Most of the user documentation exists in the form of unpublished drafts on:

- JICM introduction
- Ground combat
- Air combat
- Theater combat operations
- Naval and amphibious operations
- Lift and movement
- Map Graphics in JICM 1.0

[1]All documents cited here are publications of RAND and may be obtained by contacting Dan Fox or Bruce Bennett at RAND.

- JICM orders
- JICM displays
- System manager's guide.

Some *RSAS Newsletter* articles have also provided basic user information:

- Robert Weissler, "RSAS Consolidation: Simplifying Use and Maintenance," *RSAS Newsletter*, February 1993.
- Dan Fox, "Conducting a Strategic Bombing Campaign in the RSAS Integrated Theater Model," *Military Science & Modeling*, May 1993.

Some RSAS applications have included:

- Bruce W. Bennett, *Global 92 Analysis of Prospective Conflicts in Korea in the Next Ten Years*, RAND, N-3544-NA, 1993.
- John Y. Schrader, *Global 92 Analysis of Prospective Conflicts in the Tigris-Euphrates Watershed*, RAND, N-3545-NA, 1993.
- Bruce Pirnie, *Global 92 Analysis of Prospective Conflicts in the Persian Gulf in 2002*, RAND, N-3546-NA.
- Daniel B. Fox and John Bordeaux, *Global 92 Analysis of Prospective Conflicts in Central Europe in 2002*, RAND, N-3547-NA, 1994.

Other user or reference manuals of note are:

- Lynn Anderson, Charles L. Batten, Rosalind A. Chambers, and Sue F. Payne, *Self-Teaching Guide to RAND's Text Processor*, RAND, N-2056–1-RCC, March 1986.
- Norman Z. Shapiro, H. Edward Hall, Robert H. Anderson, Mark LaCasse, Marrietta S. Gillogly, and Robert Weissler, *The RAND-ABEL™ Programming Language: Reference Manual*, RAND, N-2367–1-NA, December 1988. This document is obsolete.

Analyst Manuals

Documentation for analysts is being prepared. In addition, the following references already exist:

- Patrick Allen, *Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models*, RAND, N-3423-NA, 1992.
- Unpublished draft on strategic mobility.

JICM Future of Warfare Work

A major JICM theme in the last several years has been better understanding the future of warfare and its implications for analysis and modeling. Several documents that describe parts of this work are:

- Bruce W. Bennett, Sam Gardiner, Daniel B. Fox, and Nicholas K. J. Witney, *Theater Analysis and Modeling in an Era of Uncertainty: The Present and Future of Warfare*, RAND, MR-380-NA, 1994.
- Bruce W. Bennett, Meg Cecchine, Daniel B. Fox, and Sam B. Gardiner, *Technology and Innovations in Future Warfare: Wargaming the Persian Gulf Case*, RAND, N-3603-NA/OSD/AF/A, 1993.

In addition, a wide range of *RSAS Newsletter* articles deals with this subject, including:[2]

- Bruce Bennett, "The Future of War—Initial Wargame Observations," *RSAS Newsletter*, November 1992.
- Dan Fox and Bruce Bennett, "The Future Military Environment and Military Modeling," *RSAS Newsletter*, November 1992.
- Sam Gardiner, "The Logic of Operational Art," *RSAS Newsletter*, November 1992.
- Sam Gardiner, "It Isn't Clear Ahead, But I Think I Can See the Edges of the Road: The Character of Future Warfare," *RSAS Newsletter*, November 1992.
- Bruce Bennett, "Defining a Structure for Analyzing Major Regional Contingencies," *RSAS Newsletter*, February 1993.
- Dan Fox, "Counter-Capability Air Campaigns," *RSAS Newsletter*, February 1993.
- Bruce Bennett, "Operational-Level Analysis and Modeling," *RSAS Newsletter*, February 1993.
- Sam Gardiner, "Microworlds: An Alternative to Scenarios," *RSAS Newsletter*, February 1993.
- Sam Gardiner, "Playing with Nuclear Weapons," *RSAS Newsletter*, February 1993.
- Bruce Bennett, "A Counter-Capability Framework for Evaluating Military Capabilities," *RSAS Newsletter*, February 1993.

[2]Past issues of the *RSAS Newsletter* may be obtained from Daniel Fox or Bruce Bennett. In May 1993, the name of the *RSAS Newsletter* was changed to *Military Science & Modeling*.

- Bruce Bennett and Patrick Allen, "The Discontinuity in Theater Analysis and Modeling," *Military Science & Modeling*, May 1993.
- Bruce Bennett, "Asymmetrical Battles," *Military Science & Modeling*, May 1993.
- Sam Gardiner, "The Nonlethal Revolution in Warfare: Maybe Not Such a Revolution," *Military Science & Modeling*, May 1993.
- Bruce Bennett, "The Value of Air Power Across Some Dimensions of Future Warfare," *Military Science & Modeling*, August 1993.
- Bruce Bennett, "Countering North Korean Nuclear Proliferation," *Military Science & Modeling*, August 1993.
- Dan Fox, "Atoms for Peace," *Military Science & Modeling*, August 1993.
- Sam Gardiner, "Even Nonlethal Weapons Might Kill the Notion of Peacemaking," *Military Science & Modeling*, August 1993.
- Sam Gardiner and Bruce Pirnie, "A Perspective on the Persian Gulf Campaign," *Military Science & Modeling*, August 1993.
- Sam Gardiner, "High Tech Commandos: The Swedish Version of the Fragmented Battlefield," *Military Science & Modeling*, August 1993.
- Bruce Bennett, "How Analysis and Modeling Should Respond to the Future of War," *Military Science & Modeling*, November 1993.
- Sam Gardiner, "Playing with Mush: Gaming Lesser Contingencies," *Military Science & Modeling*, November 1993.
- Dan Fox, Bruce Bennett, and Sam Gardiner, "Future of Warfare: Examining Second- and Third-Order Consequences Through Gaming," *Military Science & Modeling*, February 1994.
- Bruce Bennett, "Defining a New Analytic Approach for Major Regional Contingencies," *Military Science & Modeling*, February 1994.
- Bruce Bennett, "Evaluating the Survivability of the Forward ROK Defensive Lines," *Military Science & Modeling*, February 1994.
- Sam Gardiner, "Deciding to Defend the Front Door, the Porch, the Yard, or the Street: The Unresolved Issue of National Security," *Military Science & Modeling*, February 1994.
- Bruce Bennett, "Validating Theater-Level Models," *Military Science & Modeling*, February 1994.

B. JICM Terms

AIP	Applications interface program. A program that provides data from the WSDS and the History Server to Graph Tool and JICM Map, which are by design generic and modular, knowing little about the application. As applications change, software maintenance is localized primarily in the AIP (although ToolTalk makes this program of declining utility in JICM 1.0).
Anabel	Anabel is an object-oriented computer language that is under development as the successor to RAND-ABEL. An early version of Anabel was used to develop JICM 1.0, but a version of Anabel with full syntax will not be available for JICM use until some time in the future.
ATO	Air tasking order. The air operations plan for command-based estimated available air-to-ground and air-to-air sorties, user inputs (planning guidance), and parameters. The ATO produces a list of aircraft packages that will be executed in each time period and the missions and targets for those packages.
authorization	Any of several conditions that may be set by Command or Government Agents, permitting or, in some cases, requiring specified actions by subordinate commands. An example is the nuclear authorization, which, if set, specifies the maximum level of nuclear weapons to use in a theater. The default value (Unspecified) for all authorizations is "No".
AWP	Analytic War Plan. A RAND-ABEL computer program viewed as representing either a command campaign plan or a government. As a plan, it embodies a strategy or concept of operations, consisting of phases, moves, orders, communications, conditional logic, authorizations, and bounds. It may follow a basic course of action but adapts to changing circumstances.
bilateral relations	The relationship between any two JICM governments, which may range from enemy to neutral to maximal ally. This relationship determines the rights (such as basing or overflight) available to forces of a given nationality and also how naval forces react to each other.
bound	Any of several conditions that may be set by the Command or Government Agents, requiring specified subordinate commands to notify a higher authority if the bound is violated. An example is the nuclear use bound, which, if set, requires a command to notify a higher authority if any nuclear weapons are used in its theater. Higher commands can exercise positive control over AWPs by means of authorizations and use bounds for management by exception. The default value (Unspecified) for all bounds is "Off" (i.e., not applicable).

C-ABEL	A form of the RAND-ABEL language thoroughly integrated with the C language source code of the Force model, within which the substantive aspects of ITM are written.
CAMPAIGN	The models of force operations and combat adjudication in the JICM. Also called the "Force Agent." CAMPAIGN is implemented in a program called camper.
CBTZ	Combat zone. The depth of a ground force command.
CMENT	The CAMPAIGN Menu Tool. The name CMENT properly refers to a particular set of menus available as an alternative Force window package if the CMENT option has been set (the default).
Command Agent	The collection of AWPs that reflect campaign plans for military commands such as SACEUR (Supreme Allied Commander, Europe) or CINC CFC (Commander in Chief, Combined Forces Command). The Command Agent is designed flexibly to allow users to develop campaign plans either entirely at the theater command level or by recognizing a series of subordinates and providing separate functions for their operations.
commands	The basic military organizations around which military campaigns are organized in the JICM. Commands are hierarchical and may be multinational. Governments can join or leave commands.
CONL	The Control Line of a ground force command. In JICM 1.0, this is the same as the MOFL, but the basic design of ITM assumes that this line will represent the forward edge of territory well controlled by a command (although enemy forces may still exist to the rear or in the force security area), forward of which (up to the MOFL) friendly and enemy forces are mixed in a nonlinear battlefield.
Control Panel	The user interface to the System Monitor. Abbreviated name is CPANEL.
control plan	A RAND-ABEL function structured as a sequence of moves, each of which can give orders, set bounds and authorizations, and perform other military or political decisionmaking. Such a plan can define the principal events of a scenario, can include adaptive logic for changing parameters or decision variables in the various agents, and can be used to define basic scenario conditions. Each move is scheduled by wake-up rules based on game time or conditions.
Data Editor	The spreadsheet-like tool formerly used in the RSAS to review and modify WSDS-A data. The Data Editor is scheduled for replacement as part of Anabel development; it has limited operational capabilities in JICM 1.0.
Delta WSDS-A	A file containing the differences between two WSDS-As. Delta WSDS-A was used as the principal RSAS scenario-definition procedure through RSAS 4.0, but that function has since been filled by control plans. Delta WSDS-A files are written in TIL.

DTG — Date time group. A way to keep track of game time as "game date" rather than "game day," in the format "ddhhmmZMMMYY."

ED — Equivalent division. An ED measures equipment strength rather than personnel or other factors and is similar to the concept of *armored division equivalents* (ADEs) widely described in the literature. One ED is defined as the score level of the 1990 U.S. 1st Armored Division without a slice of corps combat assets.

EED — Effective equivalent division. A multiplier that adjusts the ED score to reflect a number of effectiveness factors. These factors include (1) the mobilization state of the unit, (2) training's effect on force performance (the degree to which the capability of reserve units is less than that of comparably armed active-duty units), (3) combat arms (armor, infantry, artillery, helicopter, and air defense) capabilities of ground forces, (4) national fighting effectiveness (whether due to military culture, quality of training, leadership, or enthusiasm for the cause), (5) the fighting effectiveness of individual units (e.g., Iraqi Republican Guard units being more effective than regular army units), (6) command fighting effectiveness (reflecting the quality of C3I and other factors), (7) combined-operations effectiveness of nationalities and commands, (8) joint-operations effectiveness (air and ground) of nationalities and commands, (9) fighting on home territory (thus increasing motivation), (10) cohesion problems caused by attrition in combat or poor training, (11) target acquisition and C3 effects on indirect (artillery) fire, (12) surprise suffered by forces, (13) chemical-weapon degradations suffered, and (14) supply shortfalls. Currently, most of these multipliers operate on all classes of equipment equally, although one might argue that there would be greater effects on some capabilities than on others. Alternatively, the combat arms multipliers allow a user to differentiate effects by part of the force; for example, it might be important to show the capability degradation to a nation's armor forces because they have selectively suffered from reduced training opportunities.

Force window — A window opened under X Windows in which the program camper is run.

FTG — Force time group. A game time stated in game days in the format "DayN,hhmmZ."

Government Agent — The collection of AWPs that reflect national actions, such as mobilizations and force commitments to military commands and use of nuclear weapons and other unique, national systems. Approximately 100 countries are represented.

Graph Tool — The JICM graphics package used to draw line and bar charts from WSDS, history, or other data. Abbreviated name is GTOOL.

Hierarchy Tool — The JICM tool that graphically displays hierarchies of processes running in the JICM-A. Abbreviated name is HTOOL.

History Server — A program that provides data for CAMPAIGN's history file to the AIP and other tools.

Integrated Theater Model (ITM) — The theater combat model in JICM 1.0. It is a merger of the former CAMPAIGN-MT and CAMPAIGN-ALT theater models, but has been extended to allow many more substantive issues to be captured.

Interpreter — A part of System Monitor, the Interpreter allows redefinition of RAND-ABEL functions, even in the middle of a simulation run, without the need for recompiling the JICM-A. Instructions run in the Interpreter are processed much slower than in compiled RAND-ABEL; so, generally, only small parts of the simulation are interpreted.

JICM — Joint Integrated Contingency Model. An integrated set of computer programs developed for government defense agencies under the sponsorship of the Director of Net Assessment in the Office of the Secretary of Defense. The JICM consists of Command and Government political-military decision simulation models, CAMPAIGN force operations simulation models, and system software to support game-structured analysis and gaming.

JICM-A — The RAND-ABEL part of the JICM, viewed from an implementation perspective. It consists of the Command and Government Agent decision models. It is supported by the WSDS-A data base, and a set of tools and programs including the Control Panel, Data Editor, Hierarchy Tool, System Monitor, and Interpreter.

JICM-C — The part of CAMPAIGN written in C language source code and C-ABEL. Capable of running in a stand-alone mode. It is supported by the WSDS-C data base. The JICM-C program is implemented in a program called camper.

JICM-C Interface — A process-to-process interface within CAMPAIGN that can extract selected values and aggregations from the WSDS-C when requested to do so by other parts of the JICM.

JICM Map — The map graphics package developed in conjunction with ITM; it supports ITM and other JICM diplays.

JICM Tool — The JICM Tool is a special-purpose user-interface program that manages a user's JICM workspaces, allowing the user to create and employ multiple JICM environments without having to understand UNIX and procedures for moving among directories. It is also used to initiate JICM runs and allows the user to easily access JICM documentation, source code, data bases, and graphics tools.

JICM X/OpenWindows Environment — The JICM 1.0 windowing and graphics environment is based on the X Window System and runs under Sun's OpenWindows. This simulation environment also includes a set of UNIX shell language programs that start a run of the JICM on a Sun computer and provide basic window and menu features during execution. The JICM Tool user interface for configuring and managing JICM workspaces is part of this new environment.

link (geography) The JICM land network is defined by places and links. A link connects two places, and cannot intersect any other link. In combat theaters, terrain is defined along the links.

link (software) The JICM is distributed in a configuration-controlled format. The basic JICM release becomes a directory, often referred to as /p1/install. However, users cannot operate in this directory. Instead, they create a parallel working directory, which initially has links in it instead of real files. Links are a UNIX device for providing a reference to a single file in potentially multiple places. The JICM uses symbolic links, which require only enough storage to identify the location of the file being pointed to. Thus, a large file such as the JICM-A or camper (each several megabytes in size) can have multiple references (links) to it, each of which is only a few bytes in size.

log level JICM provides a variety of output logs to give users more-detailed information in areas of interest. This information is obtained by setting the log level to a value other than 0 in the desired area. For example, the user could ask for a log level of 3 for a given force or command, which would put considerable information about it in the output file.

lookahead A game within a game in which the simulation runs forward in time to illustrate a possible outcome. Running is done by saving the current state, specifying assumptions about the laws of war and ally and opponent intentions (reflecting imperfect knowledge of the world), and continuing the simulation until a specified time or condition. The state of the world at that end point is then used to assist in determining actual Agent actions.

make The JICM uses the UNIX make procedure to compile JICM source code. A make causes source code compilation, then may link the files together to create an executable (runnable) program. JICM make files tend to be fairly sophisticated so that appropriate optimization procedures can be applied and a diversity of source code types brought together.

MOFL Most forward line of own troops. The line to which the forces of a ground force command have advanced.

OPEN LOOK A graphical-user-interface (GUI) specification that Sun and AT&T developed to define a consistent look and feel of the keyboard, mouse, and screen for applications in a windowing and graphics session.

OpenWindows Sun's implementation of the X Window System, based on X11 Release 4, which adheres to the OPEN LOOK GUI specification. It includes the xnews server; OPEN LOOK window manager (olwm); programming toolkits and libraries, such as XView; and DeskSet applications, such as File Manager. JICM 1.0 is developed to run under OpenWindows version 3.0, the default environment in SunOS 4.1.3.

order	Instruction for a military force to take some kind of action (e.g., deploy to a new location) or set guidance for its use (e.g., deny overflight). Military force orders are issued to CAMPAIGN by the Command or Government Agents or by a JICM analyst-user interacting with CAMPAIGN directly via the keyboard or indirectly via a use file. Most orders take effect over time as forces gradually move to the "ordered" state.
path	A route over the ground network that can be used either for a force to administratively advance or for combat operations.
patrol area	A combination of one or more seaboxes within which a ship, task group, or MPA unit searches for opposing naval forces.
place	A defined and named location in the JICM land network. Places usually correspond to cities, such as Dallas or Seoul. Places are connected by links.
RAND-ABEL	A RAND-developed computer language used extensively in the Command and Government Agents and in some portions of CAMPAIGN. The released versions of Agent programs are in RAND-ABEL, which has been automatically translated into C language statements, then compiled into binary code. A RAND-ABEL Interpreter allows users to change compiled RAND-ABEL functions interactively.
region	The region is the grossest level of JICM geographic resolution. Data for all JICM regions are defined in data file geog.sec and include information such as the region owner, the location of the region's geographic centroid, and the values of many parameters affecting forces in the region. There are two types of JICM regions: land and sea. See Section 3.
Retargeting Tool	A graphical-spreadsheet representation of strategic targeting, including mechanisms for modifying that targeting. This tool has not been used in some time, and it is no longer considered a certified part of the JICM. Abbreviated name is RTOOL.
RSAC	RAND Strategy Assessment Center. Facilities and staff at RAND Santa Monica and Washington used to develop the JICM and to plan and assess military strategies.
RSAS	RAND Strategy Assessment System, the earlier form of the JICM.
scripted event	An instruction entered to the JICM-C that causes an event to occur, usually instantaneously, that the models might not have otherwise caused. For example, a script can instruct a breakthrough to occur or a ship to sink.
seabox	A seabox is a rectangle (with sides defined by specific latitude and longitude coordinates) that overlays at least some portion of the sea region for which it is named (it may include islands and land near coastlines), and that does not overlap any other seabox. It is a geographic concept across which transits and patrol boxes are defined.

SED	Situational equivalent division. An EED adjusted by the terrain, type of battle, and other characteristics of the ground combat situation of the force.
set	An instruction entered to the JICM-C to change a parameter value or a default model choice. Set may also be used to request a scripted event.
SFS	Situational Force Scoring. The methodology used as the basis for adjudicating the direct-fire element of close combat in the JICM. See Patrick Allen, *Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models,* RAND, N-3424-NA, 1992.
shoulder space	The ability of forces to fit on given terrain. See Patrick Allen, *Situational Force Scoring: Accounting for Combined Arms Effects in Aggregate Combat Models,* RAND, N-3424-NA, 1992.
sleep	When an agent has completed its turn at decisionmaking for a particular moment during a JICM run, it can tell System Monitor that it is going to sleep (i.e., to suspend processing indefinitely). At that time, other agents and their subordinates will be given an opportunity to run. Thereafter, an agent resumes execution only when one of its wake-up rules is triggered.
System Monitor	The JICM-A support program that controls time advances and coordinates which part of the JICM will run next when the JICM-A models are being used.
TED	Tactical equivalent division. The SED scores adjusted for the force shortages that impair the combined-arms capability of a force.
TIL	Tool Interchange Language. A language developed specifically for the JICM to provide for communication between the different JICM processes, but which is being increasingly replaced by ToolTalk.
tool	A computer program that performs a specific function in support of a more general software package such as the JICM.
ToolTalk	The Sun utility that has become the standard for interprocess communication in JICM 1.0. This set of utility software is part of OpenWindows version 3.0.
use file	A series of instructions to the JICM-C contained in a separate file. Usually, such files begin as com files, the type of file the JICM-C produces as a log of instructions given to it. Use files can then be augmented or changed in any number of ways. They can also be quickly converted to a control plan.
VV&A	Verification, validation, and accreditation.
wake-up rule	A RAND-ABEL–coded rule that evaluates to either "Yes" or "No" to indicate whether an agent, or one of its subordinate commands, will execute on its next turn. Each AWP of the JICM-A has a set of wake-up rules associated with it to determine when it is time for decisions to be made and actions to be taken.

WEI/WUV	Weapon-effectiveness index/weighted unit value. Scoring system replaced by JICM scoring system.
WSDS	World Situation Data Set. Contains all the data associated with characterizing a specific point in a JICM scenario; may be saved and returned to at will thereafter. It consists of the WSDS-A and the WSDS-C.
WSDS-A	The portion of the WSDS that supports the JICM-A. The WSDS-A is found in a file named Run/Wsds/wsds.W.
WSDS-A Server	A process-to-process interface within System Monitor that can extract or modify data values in the WSDS-A when requested to do so by other parts of the JICM.
WSDS-C	The portion of the WSDS that supports the JICM-C. The WSDS-C consists of two parts: (1) those items fixed throughout any run (such as the names of specific forces), referred to as the WSDS.Fix, and (2) those items that may vary in a run (such as parameters), referred to as the WSDS.F.
X Window System	A network-based graphics windowing system for workstations, developed by MIT, supported by a consortium of vendors, and adopted as an industry standard. The most recent version is X Version 11 (X11).

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C. Using the JICM

Bruce Bennett

The JICM is designed to be used differently than most models of military operations and combat. In many ways, the concepts underlying JICM use go back to the systems analysis framework of the 1960s,[1] from which many models and analyses in the military analytic community have diverged in subsequent years. This appendix provides a philosophical and procedural framework for JICM users from the perspective of its developers. The concepts of a model as broad as the JICM are difficult to describe comprehensively; rather, this appendix is intended as a starting point for JICM users. New users are also encouraged to discuss philosophical and procedural issues in general, and specific applications in particular, with the JICM support team so that the procedures for JICM use, and the model capabilities and limitations, can be better understood.

Modeling and Gaming Philosophy

Traditional military models are usually employed to predict conflict outcomes, to allow the analyst to draw conclusions about resource trade-offs (e.g., Am I better off purchasing two wings of F-15s or three of F-16s?), force requirements (e.g., How many B-52 sorties are required to achieve 70 percent damage against selected opposing targets?), or other issues. In contrast, the JICM design is based on several basic philosophical beliefs about modeling, analysis, and gaming:[2]

- Computer models of warfare are not predictive tools because, no matter how detailed they are, they inevitably fail to represent some issues (especially human-related variables, such as how well different commanders will perform) and cannot be expected to represent with any kind of precision phenomena with which analysts have limited or no experience.

[1]See, for example, E. S. Quade and W. I. Boucher, eds., *Systems Analysis and Policy Planning: Applications in Defense*, RAND, R-439-PR (Abridged), June 1968, especially Sections I and III.

[2]In this discussion, our concern is with models attempting to predict conflict outcomes with any kind of precision, something that the bounds of uncertainty tend to prohibit. Thus, although it might be possible to say that the United States can win some future conflict with near virtual certainty (assuming it has the will to pursue that conflict), predictions of loss rates, advance rates, and damage rates need to reflect the wide range of uncertainties that would affect those rates. By attempting to do so, the JICM, we would argue, is actually more useful than most other theater-level models in assessing resource trade-offs or force requirements, within the bounds of proper model use discussed below.

- Computer modeling should use the strengths of computers and their environment. The principal strength of computers is an ability to quickly process a large number of calculations, serving essentially as a fast and accurate bookkeeper.[3] The real questions are, How should this speed be used? and How does one exploit the computer's bookkeeping prowess?
- Warfare at the operational-strategic level is highly uncertain; computer models can assist the military community in dealing with this uncertainty if (1) the models record relatively well what is known about a particular kind of warfare, (2) the models allow relationships among what is known about a particular kind of warfare to be modified easily, and (3) the models are sufficiently fast-running to facilitate the sensitivity testing required to evaluate the uncertainties. In essence, given the state of our knowledge on modern military warfare, RAND believes that military models should be used as laboratories for studying warfare rather than as production lines attempting to provide a precision-crafted result that satisfies all demands.
- This "laboratory" concept of model usage places special demands on both the model developer and the model user. The developer must be prepared to explain what relationships were drawn and why. Where the developer perceives these relationships to be more uncertain or to have limited validity, he or she must also make provision for changing the computer's "bookkeeping" (accounting of inputs and outputs) so that alternative relationships can be examined. Model relationships must be relatively simple and transparent so that the user can understand and work with them. The user cannot simply be a technician who submits overnight batch jobs and reports program outputs with indifference; instead, the user must (1) be knowledgeable in military operations in the area of application, (2) follow the course of the model runs in some detail to understand where questions or uncertainties are likely to arise, (3) adjust inputs to correct operational anomalies or scenario discrepancies, and (4) be prepared to explain what can be concluded on the basis of model use. In the laboratory context, model usage leads more often to conclusions that answer such questions as, What issues are most important? How robust are outcomes across scenarios? and How much difference can uncertainties in different areas make?

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[3]Those not familiar with computers sometimes forget that computers are accurate, barring hardware or system software failures, in calculating whatever they have been asked; however, this accuracy does not guarantee that what they have been asked to calculate bears any resemblance to what a specific model is attempting to represent. Said differently, writing a computer program does not mean that a calculation is done right, but rather that the form of the calculation embedded in the computer program is processed as written.

- In designing such a framework for modeling, developers must be careful to balance their efforts and must be prepared to explain both ways in which their models should not be used and ways in which their models require potentially significant human intervention. For example, in a model that does not represent specific weapon-on-weapon combat interactions, it makes little sense to account for weapon-specific munition expenditures or to use the model to evaluate weapon-specific munition requirements.

This is a tough set of criteria to meet, and we would not want to claim that the JICM has met them all. Rather, these criteria provide guiding principles to our development efforts and serve as the standard against which we measure our progress. As a result, the JICM is really quite different from most other military models, requiring a different approach both in training and application.

The bottom line is critical to understanding the JICM: **The results of any given analysis should not be justified by saying "I did this with the JICM," but rather on a rational basis that shows the extent to which the JICM was used, what assumptions the analyst chose to sensitivity-test, what adjustments the analyst made to the baseline model, etc.** The results of such an analysis should stand or fall on the quality of the overall analytic procedure—only a part of which should be the baseline JICM—and on the ability of the analyst to apply that procedure and appropriately summarize the results.[4]

Some JICM and RSAS Applications

Against the above background, let us review how the JICM is being used and how the RSAS was used previously. We describe several kinds of uses, which represent only a part of the uses to date, and the level of effort required.

Conventional Arms Control

The first major RSAS application examined various conventional arms-control options for Europe in the period during which the Conventional Forces in Europe (CFE) Treaty was being negotiated. That study postulated that the objective for arms control should be the establishment of a NATO capability for *stalwart forward defense*, which was defined as a penetration of the forward area by no more than 30 kilometers along the inter-German border. The study then

[4]More broadly, we would argue that this statement is true with any model, although given the strategic-operational character of the JICM and the many parameters it uses, it is even more true with the JICM than with many other models.

did a base case of likely conflict outcomes without arms reductions and found that the then-Soviet penetration would exceed 30 kilometers. It then examined various kinds of reductions that might lead to the desired stalwart defense and concluded that such reductions would have to be highly asymmetrical, of at least a 5:1 Warsaw Pact:NATO ratio in capability.[5] Further work concluded that the best way to achieve such asymmetries was to reduce to equal force levels, as opposed to basing reductions on percentages or numbers of divisions reduced. Equal force levels became the U.S. negotiating position (and were successfully achieved).

Four people were involved in work on this study: two provided the general guidance and report writing, and two did the RSAS analysis. The principal RSAS analyst directed the model preparation and baseline cases; the supporting RSAS analyst then ran the various cases under the supervision of the principal analyst.

Strategic Balance Study

This study involved examining the strategic balance from both U.S. and Soviet perspectives. In contrast to traditional studies, a major element of the study was to assess the linkages to theater warfare that would more than likely be the stimulus for strategic warfare. For example, during the conventional phase, the United States may be able to destroy, through conventional antisubmarine warfare (ASW), all or almost all Soviet forward-based subsurface ballistic nuclear [ships] (SSBNs), reducing the time-urgent threat to U.S. command, control, and communications (C3) and bomber facilities; at the same time, Soviet special forces teams may be effective in sabotaging enough of the U.S. C3 system to lead to a ragged (poorly coordinated) execution of the strategic forces, at best. This study also attempted to identify new criteria for evaluating the capabilities of strategic forces.

Approximately five people were involved in work on this study. Several of the participants had the primary responsibility of extending and polishing the RSAS strategic data bases. The others worked primarily on designing the study, determining how to evaluate the strategic forces, establishing scenarios, testing the scenarios in the RSAS, improving RSAS war plans, developing RSAS control plans, and documenting procedures for using the strategic-forces part of the RSAS. Many of these efforts would be required whether or not the RSAS was

[5] James A. Thomson and Nanette C. Gantz, *Conventional Arms Control Revisited: Objectives in the New Phase*, RAND, N-2697-AF, December 1987.

being used; still, the final product of the effort (for example, in developing data bases) was required to be in an RSAS-specific format.

CFE and Interdiction Analysis

This study began by adjusting NATO and Warsaw Pact forces to the arms-control levels set in the Conventional Forces in Europe Treaty, then asked whether one side or the other could gain an advantage with the timing and pace of a mobilization. It then addressed whether any Warsaw Pact ground force advantages could be offset by early air interdiction against units deploying through Eastern Europe. The objective was to examine the stability of the CFE agreement both on its own merits and as augmented by potential NATO air superiority.

This study was completed by a single analyst, who performed the study, documented it, and delivered the results to the client. Use of the RSAS was central to the study and also was considered a test case for the organization supported, to help it determine the potential utility of using the RSAS itself.

Korean Military Balance

RAND was asked to support the Office of the Secretary of Defense, Director of Net Assessment (OSD/NA), in performing its balance assessment for the Korean peninsula. The specific issue RAND addressed was, If deterrence fails, what kind of conflict might result? In the last 5 to 10 years, most military analysis of conflict in Korea has been consistent. For example, "DPRK forces have increased capabilities over the recent years, but given adequate warning and timely reinforcement from U.S. forces, ROK forces can successfully defend or restore the borders in the event of a DPRK attack."[6] Our initial analysis of a Korean conflict showed similar results, although we soon became aware that many of the assumptions we were making were keyed to a European conflict and needed to be changed significantly to properly reflect likely conflict in Korea. We pursued these differences, making regular changes to CAMPAIGN-MT to reflect patterns we discovered[7] and producing interim results that we briefed widely to the intelligence and operations communities to receive further comment and

[6]Department of Defense, *1990 Joint Military Net Assessment*, Washington, D.C.: The Pentagon, March 1990, p. VI-13. The DPRK is the Democratic People's Republic of Korea (North Korea), and the ROK is the Republic of Korea (South Korea).

[7]In some cases, the changes made were to the values of existing RSAS parameters. In other cases, we changed the underlying RSAS models to reflect a more flexible set of alternatives, with new parameters that would allow RSAS users to examine these alternatives without having to change the RSAS source code.

adjustment. In the end, we concluded that the uncertainties in many critical areas (such as training and actual force employment) are great, and we were able to show that conflict results are highly sensitive to such uncertainties.

This study was performed by a single RAND analyst working with the OSD/NA sponsor. It involved a multitude of interactions in the intelligence and operations communities, including trips to Korea and travel along the southern part of the demilitarized zone (DMZ). The CAMPAIGN-MT programmer also supported this effort by making regular changes to CAMPAIGN-MT.

War Gaming

The JICM was used to support two war games, both of which had been supported by the RSAS previously.

The Naval War College's Global Series of war games is held during three weeks in July. The JICM was used in the game to adjudicate combat and provide sensitivity analysis to the game controllers. The format of Global has varied significantly over the past five years.[8] In 1992, preparatory analysis of four regional conflicts was done with the RSAS before Global to serve as a guideline for one week of war gaming at Global, then summary reports were prepared on each of the four conflicts examined.[9] In 1991, some preparatory analysis of five regional conflicts was done with the RSAS before Global. The RSAS was used to support the one week of hot-conflict war gaming at Global, then summary reports were prepared on each of the five conflicts examined.[10] Game support involved some degree of traditional move/countermove play, although it involved just as much analysis of outcome sensitivities to alternative strategies and force operations. Because projected (out to 8–10 years) force data must be prepared for Global for a number of regions, roughly 2 to 4 man-months of data base work usually go into preparing for this game. In 1991, somewhat more than a dozen RAND analysts, plus nearly a dozen other government RSAS users, participated in Global during one of the three weeks. Six RAND analysts had principal responsibility for completing the conflict summaries after the game.

The senior service colleges hold an annual JLASS (Joint Land, Aerospace, and Sea Simulation) war game, a week-long game focused on regional conflict in the Western Pacific and Korea. Before JLASS, the students from the various colleges

[8]In 1993, the JICM team supported analysis of a Persian Gulf scenario using ITM, and did other work on defining key aspects of simultaneous major regional contingencies.

[9]These cases have been documented in RAND Notes identified in Appendix A.

[10]These cases have been documented in RAND drafts identified in Appendix A.

prepare campaign plan concepts; then in the game they test these concepts through execution of the plan and response to enemy actions. A major focus of the game is learning to operate in a *joint* (cross-service) and *combined* (with allies) environment. In 1993, JLASS used the JICM as its automated adjudication method, with Suns provided for two JICM analysts to run the game. In previous years, analysts from each war college entered inputs, then coordinated game outputs with the RSAS (in 1992, five government and three RAND RSAS operators performed these functions). Game results were reviewed and adjusted as required by a control group, which met to first determine an agreed-upon course of events over the desired ten-day to two-week game step, then met again later to review model outputs and to address particularly critical events (e.g., the effects of a Backfire raid on an amphibious task force). Over the past five years, JLASS has been modified to limit the amount of preparation required (for example, the colleges usually decide to use the data base prepared for the Global Series of war games the year before, with only minor modifications), and thus the major effort occurs during the game itself.[11]

The JICM, and the RSAS before it, has also been used to support war games at the Air University, the U.S. Army War College, and the National Defense University (NDU).

Training in Joint and Combined Operations

The JICM and the RSAS have been used for 15 semesters (over eight years) in support of joint- and combined-operations classes at NDU. Each semester, these classes are taught once each week for 12 weeks, two hours per session. Classes have considered operations in AFCENT (Allied Forces, Central Europe), AFNORTH (Allied Forces, Northern Europe), AFSOUTH (Allied Forces, Southern Europe), the Persian Gulf, Turkey, and Korea. After some initial difficulties in 1986 (worrying about model detail and "gaming" the model rather than about real-world military issues), it was decided to keep the students entirely separated from the RSAS so that they would focus on the substance of the class, not on military modeling and computer operations.[12] Within this

[11]This effort was highly successful, being perhaps the most responsive gaming effort with the JICM in terms of time required for a move (the manual adjudication efforts in JLASS, not JICM operations, were the clear critical path in the adjudication process in JLASS 93) and substantive issues handled by the JICM.

[12]Students are given a very short description of the JICM and told that it will serve as a bookkeeper in handling their operational choices; they are also told that if classroom consensus differs from JICM results, the JICM results will be adjusted by scripting a change. The rationale here is that the students at NDU have significant operational experience and may understand the character of a particular operation or issue better than the original modeler who developed any given part of the JICM; the faculty carefully controls these decisions.

approach, the students are initially briefed on a warfare scenario in which a baseline wartime outcome is presented. The students are then asked to specify how they might use their forces (usually specifying several possible options) to achieve a better outcome (relative to the baseline). They make these choices through several phases of combat and across several types of action (e.g., commitment of reserves and use of operational-level fires). The following week, the students are briefed on how their actions might affect the outcome, then are allowed to either modify their choices from the previous week or move to another set of decisions.

This effort employs one or more instructors per class who are sufficiently familiar with the JICM to brief the results each week. One or more JICM analysts have been used to generate the results. These analysts have generally participated in the classroom discussion, and most have commonly taught or assisted in teaching the classes.

The JICM and the RSAS have also been used to support classes at the U.S. Army War College and the U.S. Naval War College.

Maritime Linkages Study

The Naval Postgraduate School (NPS) has looked at a number of maritime issues with the JICM and the RSAS. It has focused particularly on issues relating to the strategic nuclear forces, although doing so has involved a variety of other issues.[13] The JICM and the RSAS have been used in NPS research projects, in dissertation support, and in curriculum support.

This effort involves two principal JICM and/or RSAS analysts actually running the JICM/RSAS and several other individuals providing review and direction to the efforts.

Analysis and/or Gaming with the JICM

The JICM is not a standard model of military operations or warfare. The *standard* models usually focus on model outcomes at the conclusion of a conflict scenario and have as an objective the prediction of military requirements or trade-offs in a specific contingency. By contrast, the JICM recognizes that warfare at the theater

[13]See, for example, the early plans for this work as outlined in James John Tritten and Ralph Norman Channell, *The RAND Strategy Assessment System at the Naval Postgraduate School,* Monterey, Calif.: Naval Postgraduate School, NPS-56-88-010, March 1988. Anyone interested should contact Professor Channell for other documentation.

or strategic level is so complex and uncertain that the more appropriate questions are: What issues affect outcomes the most? How sensitive are outcomes to these issues? How robust are the outcomes over scenarios and uncertainties? and How do the various issues and capabilities interact? The last question makes it clear that a JICM analyst is as interested in the scenario and character of operations played in it as he or she is in the outcomes of that scenario. Thus, the JICM is interactive not just to allow analysts to enter new instructions as a scenario proceeds but, more important, to allow the analyst to review how the scenario is proceeding.

This discussion highlights the basic paradigms of analytic war gaming that underlie the JICM. They are organized into three categories:

- how to structure an analytic or gaming effort
- analysis of a scenario or run
- analysis across scenarios and sensitivities.

The character of these paradigms is explained below by category. Note that there are many ways to use the JICM and many operational variants of the themes described below; this material is presented more to condition a mind-set than to provide an absolute road map on how to do analysis and gaming with the JICM.

How to Structure an Analytic or Gaming Effort

When structuring an analytic or gaming effort, the analyst must first determine the objectives of the analysis. Typical classes of objectives in military analysis or gaming are (1) assessment of the relative capabilities of each side in a prospective conflict to achieve its objectives, (2) evaluation of resource requirements or trade-offs for a military operation, (3) assessment of strategy and operational art alternatives, (4) determination of the capabilities and assistance required to support a military operation, and (5) training of personnel relative to a type of military operation. Within these broad classes, the analyst must identify his or her objectives in very specific terms, which requires determining the specific issues to be focused on, constraints to be considered, and objective functions (and figures of merit) to be used.

Two examples will help to illustrate this point. First, the analysis of the Korean balance mentioned above had as its objective the assessment of relative conflict outcomes should war occur in Korea. Given the posture and doctrine of both the South and North Korean military forces, it was determined that the key issue was whether North Korean forces could penetrate the forward South Korean defenses

within the first week or so of conflict.[14] Thus, the key measure of success was the maximum penetration of the North Korean forces over the first week or so of the campaign, with secondary measures associated with the relative amount of force lost on each side during this process.[15] Other critical issues were the employment and effect of artillery on each side, the relative training effectiveness of each side, the tactics and doctrine of each side, the influence of failed defensive lines, and the employment and effectiveness of tactical aviation.

Second, the NDU class in joint and combined operations mentioned above had as one of its objectives the training of multiservice students in joint and combined operations in Europe, the Persian Gulf, and Korea. Specific issues to be considered included the use of reserves and operational fires (especially air). There was no firm requirement for specific figures of merit, but rather a willingness to allow the students to focus on figures of merit they felt comfortable with, as long as important issues were not lost. Because the class was to emphasize military operations, it was decided to downplay the political constraints on military operations, making them a secondary rather than a primary issue.

Given these considerations, the analyst must determine what methodology and tools are appropriate for the effort. The word *tools* is plural here because we do not presume that the JICM is the only model an analyst/gamer might want to use; in fact, no model will be perfect for answering every problem. Instead, we believe that most analytic organizations will begin working with families of models, in which more-detailed models are used to address tactical issues and tune the more-aggregate models, which can address operational issues. The JICM has been designed to operate in this kind of framework, allowing analysts to adjust baseline parameter values and other representations based on work with more-detailed modeling, exercises, or other results. For example, an analyst wishing to evaluate trade-offs in aircraft force mixes would first use a series of detailed models to evaluate the relative performance of each kind of aircraft in the various missions considered. The analyst could then use these results to tune JICM parameters and use the JICM to examine how different mixes and employment of aircraft affect overall conflict performance from a joint- and

[14]Extensive analysis tended to show that a rapid North Korean victory in front of Seoul gave it sufficient momentum to seriously threaten the remainder of the peninsula, whereas a slow victory or a defeat in front of Seoul doomed North Korea to face the power of the United States and whatever coalition it could bring to bear on the situation. Thus, while some might argue that the primary North Korean objective would be to capture Seoul, we believe it more likely that North Korean forces would seek to bypass and surround Seoul, having learned from the Korean War that operations to secure Seoul often took considerable time, which might lead to a yielding of the initiative in the overall campaign.

[15]Force lost was not a primary measure of effectiveness because it tended to correlate with the speed with which the North Korean forces penetrated the forward defenses.

combined-operations perspective. In doing this analysis, neither the more-detailed models nor the JICM would, by themselves, be sufficient to address the force trade-off issues; used in combination, they can address the range of issues that must be considered in such an analysis. JICM users are invited to discuss particular applications with the JICM support staff if questions arise about the appropriate analytic approach.

Once JICM is chosen for an application, specific methodology is selected according to the objectives and situation in which the JICM will be used. For example, in the training case cited above, it was determined that the purpose and duration of the class and the amount of material to be dealt with made it impossible to train the students in the use of the JICM. As a result, the JICM was used as a bookkeeper for the decisions of the students; a staff member translated student inputs into the JICM framework and briefed JICM results.

The next step is to establish a baseline scenario for the user's specific application. To aid in this process, four baseline scenarios are provided with the JICM, covering conflicts in Poland, Turkey, the Persian Gulf, and Korea. These cases were developed in support of the Global Series of war games sponsored by the U.S. Naval War College, and other JICM analyses. From these, the user can then tailor a specific baseline for the desired application. In the Korean balance case, the baseline was defined for current forces, against which future force capabilities were considered as alternatives. Moreover, that case was further defined by a specific mobilization and conflict scenario (for example, How much time would South Korea have to mobilize? and How much time would North Korea require?). The analyst must also determine specific force performance and capability parameters as part of the baseline, paying special attention to forces whose effect must be adjudicated off-line (for example, Will North Korean SOF have a 5 percent or 20 percent effect on U.S. sortie generation? and Over what time frame?).

Note that with the JICM, the baseline is usually defined in general terms before analysis begins, but then potentially many hours or days of analysis must be focused on determining the details of the baseline. During that time, the JICM may be run dozens of times, with problems found and identified, until a final baseline is achieved (this process will be described further below). The objective of this process is to establish a plausible scenario that fits with the analytic objectives; the process is more like contingency planning than batch processing of a scenario. For example, in the European training case introduced above, in which a NATO force faced a Russian-led coalition at the turn of the century, the NATO players were allowed to take first offensive actions (the sinking of a Soviet cruiser inside a carrier-exclusion zone) despite our sense that NATO might not

have the political will for such an action, because this move was a key component of the NATO players' overall defensive strategy. While this might, as a result, lead to a less-plausible scenario from the political perspective, it met the objectives of the exercise by allowing the students to consider a possible course of action and the resulting consequences.

Next, the user establishes scenario variants to be run. In the Korean balance case, these variants corresponded to alternative North and South Korean force employment concepts (e.g., a North Korean main attack through the Kaesong-Munsan approach or through the Chorwon approach, or U.S. and South Korean focus on the offensive counter-air mission or on the offensive air [troop] support mission). In the NDU European case, the base case was a short-warning Russian attack, and the principal variant involved reconstitution by both sides over several years before the conflict. Thus, the scenario variants seek to explore the alternative ways the conflict could proceed, in recognition that a baseline case is at best a low-probability event among a wide array of alternatives.[16] Working from a baseline, this process is usually somewhat less intensive than *establishing* the baseline scenario (the analyst will still likely make several runs per scenario variant, trying to establish the scenario variant details) but is very intensive when comparing outcomes over time with the baseline.[17]

The analysis procedure concludes with sensitivity testing of results. Normally, the most important sensitivities to test are differences in scenario, critical parameter values, and model options. In this process, analysts need to focus on differences in operations, as well as on differences in outcomes. For example, in the Korean balance case, if some South Korean reserve units are unable to reach their assigned positions before those positions are overrun, how would those units be employed? Obviously, as scenario and other factors change, the analyst

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[16]Historically, it is interesting to note that, in an unpublished summary of RSAS 4.0, we defined the purpose of the scenario variants somewhat differently. In that earlier period (1989) when the world had much more stable notions of prospective conflicts, scenario variants were generally used to test the hypotheses of the analysis, allowing the analyst to evaluate the study objectives. For example, an arms-control study would identify alternative measures that could be employed in an agreement, and the scenario variants would test those alternatives to determine if they performed better. In the past several years, however, we have seen much more use of scenario variants to examine the range of possible conflict scenarios, some of which may involve specific measures' being evaluated in a study, because, for any given prospective conflict, this range appears to be extremely broad.

[17]Eventually, it is desirable to develop Analytic War Plans (AWPs) that support the scenario. Initially, such plans may be little more than a script associated with the baseline scenario. Then, as the analyst moves on to scenario variants, the AWPs can be adjusted and conditional logic added to have them handle the various contingencies identified. For example, if in a baseline scenario a 15-day air campaign precedes ground combat in some theater, appropriate conditional logic should be built over time. The logic might enable the air campaign to be extended for 30 days or more *if* good returns continue to be achieved or ground forces are not ready; or the campaign might be terminated after only one week *if* it is not achieving objectives, *if* the attrition suffered is too high, or *if* it achieves objectives so well that ground combat could be begun earlier. RAND analysts did create such AWPs for a previous version of the RSAS; we have not yet reached such a level of experience with JICM 1.0.

cannot expect to make a run to evaluate each sensitivity, but rather must plan some mixture of runs (likely a small subset of all possibilities) to account for issues not raised in the baseline or scenario variant cases. This is the process used both to determine the robustness of outcomes and to evaluate many of the interactions between critical factors. For example, in a future Persian Gulf scenario, an Iraqi force with cruise missile–delivered terminally guided weapons, in conjunction with an extensive Iranian captorlike mine capability and Scuds with improved accuracy and explosive power, might deny prompt U.S. entry into the eastern part of Saudi Arabia and force a much longer and more costly campaign through western Saudi Arabia.[18]

In the end, the analyst must synthesize all this effort into a set of outcomes and study or training results. This process often leads the analyst back to an alternative sensitivity or scenario variant and is itself often an iterative process. In most cases, the results are as much a function of things learned while running scenarios as they are a comparison of output figures of merit across scenarios.

Analysis of a Scenario or Run

The first step in developing any scenario is determining the pattern of events that is desired to support the analysis. For example, What will be the length of mobilization? What forces will be deployed when? and How will various areas be defended? Although some military planners can go a long way in specifying the details of an operation, in practice we have discovered that even the best planners forget or do not know some aspects critical to a scenario, especially when working outside of their immediate area of expertise. And in a global warfare model like the JICM, there are relatively few experts in all the aspects of warfare that must be considered in any given scenario.

With computer models of warfare proliferating and many becoming extremely complex, the importance of establishing expectations for outcomes is very high. That is, very few military models have been or can be fully verified for correctness, let alone fully validated against appropriate military phenomena. Instead, verification and validation usually focus on key algorithms and a few paths through the entire simulation. Invariably, analysts then decide to take other paths through the simulation and run the potential of encountering bugs in either model implementation or concept. Unless the user has expectations for how the simulated military operation ought to proceed and what results it ought

[18]See, for example, Bruce W. Bennett, Meg Cecchine, Daniel B. Fox, and Sam B. Gardiner, *Technology and Innovations in Future Warfare: Wargaming the Persian Gulf Case*, N-3603-NA/OSD/AF/A, 1993.

to achieve, he or she will be unable to ensure that the computer model has produced a reasonable product. This is true of almost any military model and is especially true of any model as large as the JICM.

The bottom line in running any JICM scenario is: Did the results develop as expected? Note the use of the word *develop*, because we are as concerned about the progress of the military operations over time and whether certain parts of the operations worked as expected as we are about the outcome figures of merit. For example, in a naval warfare scenario, did the ships deploy in roughly the proper sequence and number and with the proper delays? In evaluating bomber prelaunch survival, did survival vary appropriately by region of the country? In ground combat, if a breakthrough occurs in a theater, does the defender make appropriate attempts to reinforce the broken sector? If not, are there good reasons why it did not?

An important place to look for such problems is in the JICM output logs, which will record errors and warnings that users need to review; the errors range from syntax errors (e.g., specifying the wrong parameters or misspelling something) to procedural errors (e.g., trying to target a carrier battle group in port, when instead one needs to target the port in such a case). But many problems can exist without such errors' being recorded in the logs (e.g., trying to deploy forces to Europe without mobilizing airlift); in the JICM full system, the user can write wake-up rules that check the reasonableness of certain aspects of the scenario, then alert the analyst when the preestablished conditions of reasonableness are not met. In many cases, the user must also examine operations and events about which he or she had no specific expectations but that still must be considered to verify the reasonableness of a particular outcome.

When some part of a military operation does not develop as expected, what happened? Working from an outcome that is different from what was expected, the analyst must usually determine first what could have caused the difference. If a force did not arrive at the expected place, it might not have arrived because (1) it was not mobilized and alerted, (2) it took longer to prepare for deployment than expected, (3) it was not ordered to deploy, (4) there were insufficient lift assets to move it, or (5) it was not allowed politically to deploy to the area it wanted. Note that analysts unfamiliar with military operations in the given area are not going to be able to prepare such a list and thus will be lucky to find the problem. Once a list of possibilities exists, the analyst must determine how to examine each of these possibilities in the JICM. In some cases, a simple JICM display or graph can provide an indication of whether one of these possibilities is or is not a problem. In the example above, the mobility display in CAMPAIGN will clearly indicate whether sufficient lift resources were available. In other

cases, the critical point for identifying the problem has passed, and the user must return to an earlier point in the scenario and examine the situation at that point. In such cases, the analyst will likely want to set a log level to increase the output detail in the area associated with the problem.

After pursuing such issues, we find that in most cases the problem is discovered, and some modest effort is required to correct the scenario and achieve the desired result. However, the analyst sometimes learns that an unexpected relationship has complicated the operation; in such cases the actual sequence of events produced by the JICM may be correct, but the analyst may still need to adjust inputs, perhaps substantially, to meet study objectives. Alternatively, the analyst sometimes cannot explain the problem and suspects a modeling error (and is correct in this suspicion some fraction of the time). In such a case, the analyst needs to contact the JICM support team, which will assist in problem diagnosis and bug resolution, if a bug exists. In any of these cases, the user almost invariably must rerun the scenario being attempted, because even a small change in outcome at any given stage can snowball into significant changes at later stages.

The analyst is also strongly advised to keep a notebook (not unlike the scientist's laboratory notebook), recording the character of each problem and how it was resolved. Then, should such a problem recur at a later date, the analyst can address it more efficiently. In many instances, the most important output of this process is what the analyst learns about military operations and how to use the JICM, a record of which can be invaluable. To facilitate this process, RAND is providing a "user notes" section in CAMPAIGN's on-line documentation and will consider adding such sections to other parts of the JICM.

Analysis Across Scenarios and Sensitivities

After the user has established two or more scenarios, the process of comparing scenarios begins. Most JICM analysts find that the graphical comparison of history file data (using Graph Tool) between scenarios is the best procedure for beginning this process.[19] Graphics provide a simple process for comparing a large amount of data, and the human eye is generally adept at identifying differences (especially unexpected differences). Our analysts usually also

[19]Graph Tool provides a capability to predefine a series of graphical comparisons, which can speed this process. For example, the analyst in the Korean balance case cited above might prepare a package that displays all of the FLOT traces in the Chorwon corridor simultaneously; having done so, he can vary the files submitted to this package and thus examine the Chorwon corridor FLOTs from any number of scenarios.

attempt to identify significant events (e.g., the first major breakthrough in a theater, the loss of air control over a FLOT, the establishment of sea control in a region, or the first launch of nuclear weapons) and compare when these events occur over time in various scenarios.

In making these comparisons, the analyst is again asking, Are these differences reasonable? If not, why not? If differences seem illogical, the analyst must then search for a reason, much as in evaluating a problem in a single run. The major difference is that the problem could occur in either scenario being compared, and thus both must be examined and considered in some detail. It is also important to point out that the JICM is an analytic war gaming system that sometimes produces nonmonotonic results. Thus, an improvement in some input factor may lead to a poorer outcome for that side; upon closer inspection, it may even seem reasonable that such a result occurs. For example, adding divisions to a defense might cause the defender to hold an untenable line a bit longer, with the result that the subsequent breakthrough and encirclement destroys much larger forces than would have been lost had the line been abandoned early on. As this example indicates, the analyst must be prepared to look not only at the character of outcomes but also at the relative course of events to determine why unexpected differences occur. We sometimes find it necessary to rerun the two apparently inconsistent cases in parallel, monitoring the development of the scenario closely to determine why the differences occurred.

Once the reason behind differences is understood, the analyst must then resolve how to handle the differences. Using the case where the addition of defensive forces leads to a worse defeat, the analyst supporting training in joint and combined operations would likely want to dwell for some period on this kind of phenomenon and its implications for commitment of reserves. Alternatively, the resource analyst, for whom continuity is critical, may want to revise the scenario used in the enhanced-forces case and have the defender play the same strategy as in the baseline case (withdrawing early rather than later), in which case the defender should then do better with the enhanced forces. The main point is that inconsistent results should be handled differently according to the objectives of the analysis.

Fortunately, in most cases the differences found between scenarios are consistent with what an analyst might expect. For example, the addition of forces allows a defender to maintain a cohesive defense rather than suffering a breakthrough; a better attack submarine improves the ability of that side to achieve sea control in some area.

At first blush, analysts may be tempted to follow traditional procedures in evaluating model outcomes and develop conclusions such as, "The addition of two divisions allows the defender to sustain 37 percent less loss of territory." Instead, we feel that JICM outputs should be summarized in terms such as

- The addition of two divisions only modestly (or significantly) affects the ability of the defender to hold terrain [the relative magnitude of results].[20]
- The addition of two divisions allows the defender to hold terrain better except when these divisions do not arrive in the theater before D+10 (10 days after the start of the conflict) [how robust are the results?].
- The addition of two divisions only modestly affects the ability of the defender to hold terrain, but adding an independent attack helicopter brigade to each corps across the front would significantly affect the ability of the defender to hold terrain, assuming attack helicopters can average at least 0.5 combat vehicle kills per sortie [what makes a difference?].
- The addition of a new air defense weapon in a sector substantially increases the attrition caused to opposing attack helicopters, which in turn reduces the long-term damage the helicopters can cause, reducing the likelihood that the opponent will achieve a breakthrough and substantially reducing the destruction it could cause if a breakthrough is achieved [the interactions of factors].

Analysts should carefully avoid the use of spurious precision: The JICM is an aggregated model, and the areas it deals with are sufficiently uncertain to warrant due care in presenting any results. In all cases, we recommend that outcomes be well caveated and that the audience be warned about not extending conclusions beyond the context in which they are offered. We recognize that this is a very different procedure from the norm used in the analytic community and recommend that JICM users spend some time with the JICM support team when framing conclusions from initial JICM studies.

Perhaps more important in many cases, the user should be prepared to summarize lessons learned as a result of a JICM study. Much of the learning occurs during the early stages of the analysis, when the user discovers that forces did not operate as expected or interactions existed that had not been expected. Too often, such lessons are lost from eventual study conclusions, in part because of when they were discovered (early in the analysis) and in part because they are not directly responsive to the study objectives. At the very least, we recommend

[20]After each example, we state the more general kind of issue addressed inside brackets, to clarify what we feel to be the kind of results appropriate for presentation.

an appendix or a memorandum for the record that explains the lessons learned, in part as a reminder to the analysts the next time they work a similar problem and in part as a log for new analysts in the same agency as they begin to use the JICM.